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ABSTRACT

Reported is part 2 of a two-part publication which presents the narrative materials for the teaching of the concept--the development of atomic energy and its social implications. This publication is the result of a study to determine the feasibility of teaching scientific concepts related to the social and historical developments of science and selected concepts related to atomic energy. Presented in this section is a consideration of the scientist and his work toward a more sensible administration of atomic energy, as well as some of the benefits and risks of using atomic energy, and the products of atomic energy and what they may have in store for the future. Chapters 11 and 12 are included as well as a narrative quote source list and bibliography. An extensive teacher's guide, giving points to consider and teaching suggestions for each chapter, is included in the manuscript. An annotated bibliography of films used in the unit, available from the Atomic Energy Commission, is presented along with slide narratives. (EB)

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Practical Paper No. 303 (Part 2 of 2 Parts)

THE FEASIBILITY OF TEACHING SCIENCE VIA A SOCIO-HISTORICAL APPROACH

Part II
Classroom Materials

U S DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
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by
Michael Lawrence Agin

Report from the Project on
Elementary Science--Man and
the Environment

Milton O. Pella
Principal Investigator

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STATEMENT OF FOCUS

Individually Guided Education (IGE) is a new comprehensive system of elementary education. The following components of the IGE system are in varying stages of development and implementation: a new organization for instruction and related administrative arrangements; a model of instructional programing for the individual student; and curriculum components in prereading, reading, mathematics, motivation, and environmental education. The development of other curriculum components, of a system for managing instruction by computer, and of instructional strategies is needed to complete the system. Continuing programmatic research is required to provide a sound knowledge base for the components under development and for improved second generation components. Finally, systematic implementation is essential so that the products will function properly in the IGE schools.

The Center plans and carries out the research, development, and implementation components of its IGE program in this sequence: (1) identify the needs and delimit the component problem area; (2) assess the possible constraints--financial resources and availability of staff; (3) formulate general plans and specific procedures for solving the problems; (4) secure and allocate human and material resources to carry out the plans; (5) provide for effective communication among personnel and efficient management of activities and resources; and (6) evaluate the effectiveness of each activity and its contribution to the total program and correct any difficulties through feedback mechanisms and appropriate management techniques.

A self-renewing system of elementary education is projected in each participating elementary school, i.e., one which is less dependent on external sources for direction and is more responsive to the needs of the children attending each particular school. In the IGE schools, Center-developed and other curriculum products compatible with the Center's instructional programing model will lead to higher morale and job satisfaction among educational personnel. Each developmental product makes its unique contribution to IGE as it is implemented in the schools. The various research components add to the knowledge of Center practitioners, developers, and theorists.

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TABLE OF CONTENTS - PART II.

APPENDIX Page

E. NARRATIVE FOR THE DEVELOPMENT OF ATOMIC ENERGY AND ITS SOCIAL IMPLICATIONS

SECTION I. THE DEVELOPMENT OF FAITH IN SCIENCE BY SOCIETY....... 1

CHAPTER I. AN INTRODUCTION TO NUCLEAR ENERGY, SCIENTISTS, AND SOCIETY.. 3
CHAPTER II. THE BEGINNINGS OF SCIENCE....... 13
CHAPTER III. GREEK SCIENCE.................. 33
CHAPTER IV. THE ECLIPSE OF SCIENCE.......... 61
CHAPTER V. REBIRTH OF SCIENCE.............. 81
CHAPTER VI. 18TH, 19TH, AND 20TH CENTURY SCIENCE............ 109

SECTION II. EXCESS FAITH IN SCIENCE BY SOCIETY (SCIENTISM).... 143

CHAPTER VII. FROM RADIOACTIVITY TO THE NEUTRON.................. 145
CHAPTER VIII. U.S. SCIENCE AND POLITICS MERGE.............. 183
CHAPTER IX. FROM THE LABORATORY TO ALAMOGORDO........ 211
CHAPTER X. SCIENCE WINS THE WAR............ 241

SECTION III. THE CHANGING IMAGE OF SCIENCE FROM A NATIONAL TO AN INTERNATIONAL FORCE......... 269

CHAPTER XI. ATOMIC ENERGY AND SOCIETY....... 271
CHAPTER XII. ATOMIC ENERGY, SCIENCE, AND THE FUTURE......... 299

NARRATIVE QUOTE SOURCES........................ 316
BIBLIOGRAPHY................................... 323

F. TEACHER'S GUIDE.............................. 333

G. MOTION PICTURE DESCRIPTIONS.................. 385

H. SLIDE NARRATIVE.............................. 387

ABSTRACT

The purpose of this study was to determine the feasibility of teaching science via a socio-historical approach utilizing selected concepts related to the social and historical developments of science and selected concepts related to atomic energy. The criteria used to assess the success of the approach were:

1. A significant increase in subject matter knowledge possessed by the students participating in the study.

2. A high level of student interest toward the socio-historical approach as indicated by the responses of the students to an interest questionnaire.

3. An increase in student understanding of knowledge related to

   a. science and scientists,
   b. science-society interrelationships, and
   c. the atom and atomic energy.

The instructional materials for the study included a) 12 chapters of textual materials developed by the investigator, b) a test based on the text, c) a series of slides, and d) four selected motion picture films. The investigator, who utilized a lecture-discussion technique with an accompanying slide presentation, taught the instructional unit to two different high school populations during two 14-day periods of instruction. The populations included in the study included 107 twelfth-grade students in American Problems classes (School A) and 76 tenth-, eleventh-, and twelfth-grade students in Chemistry classes (School B).

A 90-item multiple choice test, administered as a pretest and posttest to both groups, yielded three subtest scores--science and scientists, science-society interrelationships, and the atom and atomic energy--and a total score for each student. Mean gains--the difference between pretest and posttest class mean scores--for the subtests and total test were tested statistically and found to be significant for both schools. Correlation coefficients of individual scores on the test and IQ did not reveal any consistent pattern of relationship.

Student responses to a questionnaire indicate that a majority of the students in both schools expressed a positive opinion toward the interest producing potential of the unit and indicated that the reading material was at least at the same level of difficulty as material experienced in science classes. In addition, at least 83% of the students of School A and 91% of School B felt that the unit increased their understanding of a) science and scientists,

b) science-society interrelationships, and c) the atom and atomic energy.

On the basis of the conditions of the study, namely the procedures utilized and the nature of the populations included, it was concluded that teaching via a socio-historical approach is feasible since the performance of the students met the criteria for acceptance.

THE DEVELOPMENT OF ATOMIC ENERGY
AND ITS SOCIAL IMPLICATIONS

SECTION III.

THE CHANGING IMAGE OF SCIENCE FROM A NATIONAL TO AN INTERNATIONAL FORCE

269/270

CHAPTER XI. ATOMIC ENERGY AND SOCIETY

The Atomic Scientists in Politics

The bombing of Hiroshima and Nagasaki was instrumental in bringing World War II to an end (most scientists, politicians, and military men agree that the A-bomb shortened the war, but did not end it). On September 2, 1945 aboard the battleship Missouri, the Japanese signed an unconditional surrender--World War II was officially over.

Scientists found themselves in a very unusual position. They were public heroes because they helped to defeat the enemy. These scientists had created a powerful instrument and could no longer be dismissed as long-hairs or idle tinkerers. Now they were looked upon as a major source of national power. Almost overnight they went from obscurity to public figures. As one scientist recalls:

> Suddenly physicists were exhibited as lions at Washington tea-parties, were invited to conventions of social scientists, where their opinions on society were respectfully listened to by life-long experts in the field, attended conventions of religious orders and discoursed on theology, were asked to endorse plans for world government, and to give simplified lectures on the nucleus to Congressional committees. (11-1)

However, many scientists felt guilt and anger. Guilt because they helped create the new weapon and anger at the government for using it. Many refused to do any further work on military projects. Norbert Wiener (early developer of information processing--cybernetics) took the point of view that civilian governments would use any weapon that was developed by science and advocated the withdrawal of all scientists from military research. He later refused to release some of his research findings to the U.S. Air Force.

Edward Teller took the other point of view. He advised scientists to pursue their research with an ultimate confidence in the benefit of science. He states:

> The men of the Kremlin showed by their actions that in the world to come military power will be of the greatest importance. It is the duty of those of us who made the first atomic bombs to find out all the dangers and all the terrors of our discovery. We have eaten of the tree of knowledge and as scientists we must have the faith--perhaps the temerity--to believe that knowledge in the end will be turned into blessing. At least we should have the conviction that if we should give way to fear and if we should fail to explore the limits of human power we shall surely be lost. (11-2)

Most scientists did not follow Wiener's or Teller's lead; the war was over and they wanted to return to their civilian careers. Although their attention was shifted from war to peace they still carried a concern for the utilization of atomic energy. As weeks passed it became apparent that many scientists were not going to ignore the military applications of science.

The big question for a large number of scientists was "How can we influence our government's use of nuclear energy?" The Bohr Memorandum and the Franck Report were steps in this direction but they were not forceful enough. Many scientists felt that they had a special responsibility toward society but they could not define this responsibility or the action they would take.

Scientists were not sure of the political techniques and channels to follow but entered post-war politics. This was something new for United States scientists. Politics in a science laboratory was an unwelcome intruder, but many laboratories became meeting places of politically active scientists. Scientists such as Oppenheimer, Lawrence, A. Compton, and J. Conant became strong advocates of the control of atomic energy. Their work toward control of atomic energy involved the solution of two issues. As one scientist summarizes:

> The original program of the atomic scientists consisted of two important issues: one domestic, the other international. The domestic issue was to place the direction of atomic development into the hands of a civilian agency and to enact legislation which

> secures to our people the maximum benefits of the new discoveries, and which does not place unnecessary restrictions on the scientist working on atomic energy.
>
> The international issue was to get agreement and cooperation between all nations so that the people of the whole world could work together in this new and wonderful field of human endeavor. This was the positive side of the international issue--but there was also a negative side, which in the minds of all of us outweighed all other questions. How shall we avoid a war in which atomic weapons and perhaps other scientific inventions would be used? (11-3)

We will consider these two issues and how scientists have been involved in the steps toward their solution.

Domestic Issue

The processes for the production of nuclear explosives and nuclear fuels are identical. A piece of uranium may become a pellet for a nuclear reactor or part of a critical mass in a nuclear weapon. Therefore, the control of military uses of nuclear energy requires the control of all aspects of the production and utilization of fissionable material. The domestic and international management of nuclear energy is based upon this need for control. There appears to be a need for agencies to encourage the development of atomic energy in all countries, and also a need to prevent the conversion of fissionable materials into nuclear weapons. The question is, "How do we do this?" Let's look at some attempts at the answer.

Atomic Energy Commission

Shortly after World War II scientists learned that certain persons in the Truman Administration and in the Congress were trying to push a bill on atomic energy through Congress. The bill--May-Johnson Bill--had been proposed by the Interim Committee but scientists were afraid that this bill would "militarize" atomic energy. As one political scientist states:

> The Bill...would have established an Atomic Energy Commission with rather arbitrary powers over the field of atomic energy, including scientific research. The reaction of most scientists was one of fear as they were convinced that military officers would come to administer science and would impose serious restrictions on dissemination of scientific knowledge. (11-4)

The bill, sponsored by the War Department, called for a part-time commission of twelve members (five scientists and engineers, three other civilians, and four military men) and excluded Presidential control. In other words, twelve men would have control over atomic energy utilizations without having to answer to the President or his Cabinet. This is what worried the scientists and they lobbied for further study of the bill.

The Senate established a Special Senate Committee, which was chaired by Senator McMahon of Connecticut. McMahon appointed physicist Edward Condon as adviser who in turn sought the advice of scientists and other national leaders about the May-Johnson Bill. Condon, with the aid of lawyers James R. Newman and Byron S. Miller, drafted an alternate bill for the committee. They accepted modifications from Truman's advisers and thus gained their support for the bill.

The May-Johnson Bill deliberately excluded executive interference, but the new bill--called the McMahon Bill--gave the President much control. President Truman, who was originally for the May-Johnson Bill, shifted his support to the McMahon Bill. While this was taking place, scientists generated public support for the new bill. They conducted a campaign which consisted of forums, letter-writing, and publicity to gain support for civilian control.

Their efforts were successful; the McMahon Bill was approved in July, 1946. The Atomic Energy Act (formerly the McMahon Bill) provided for a civilian commission--the Atomic Energy Commission (AEC)--of five members appointed by the President with Senate approval. The Commission is assisted by two advisory boards, one composed of scientists--General Advisory Committee (GAC)--and the other of military men--Military Liason Committee. Thus the scientists and military have access to the AEC via special committees.

The Atomic Energy Commission controls all aspects of atomic energy in the United States. It was established as a controlling agency free of the profit motive rather than release control of atomic energy to military or industrial interests. After the work of many scientists and many discoveries, atomic energy has become one of the United States' biggest scientific, technological, and business enterprises.

The AEC has established many National Research Laboratories (i.e., Argonee National Laboratory). It has supported the construction of nuclear reactors, controls the distribution of radioisotopes, and also controls research and development for military purposes. At the present time, scientific teams are working on research sponsored by the AEC.

The United States and many other countries have solved their domestic issues through the establishment of national atomic energy agencies. However, scientists were only partly satisfied with their success. They wanted international as well as national control, but have not yet achieved this goal. Science and society are still working on this issue.

Federation of Atomic Scientists

When the May-Johnson Bill was first proposed, U.S. scientists came together spontaneously to form various associations which eventually merged into the Federation of Atomic Scientists (now it is known as the Federation of American Scientists). Chicago--the Franck Report originated here--became the publishing center for the Federation (FAS). The Bulletin of Atomic Scientists is the forum for the exchange of member's views, both scientific and political. In addition, they attempt to inform laymen of the latest scientific and political developments.

The editors of this journal have placed a clock on the cover of the Bulletin which symbolizes the approaching atomic doom. The hands were originally at fifteen minutes to midnight (or doom) but in 1953--when the U.S. and the USSR exploded hydrogen bombs--the editors moved the minute hand to two minutes to midnight. The events of the world have prompted the editors to move back the minute hand; at this time it is ten minutes to midnight.

The International Issue

Baruch Plan

Following World War II, Henry Stimson and Vannevar Bush led a group of scientific and governmental officials in a search for a solution to the nuclear weapons dilemma. These men--influenced by Leo Szilard and Niels Bohr--advocated and supported the idea of international control of atomic energy. Finally, on November 15, 1945 the United States, Canada, and Britain announced their commitment to international control of atomic energy.

Written by Bush, this declaration called upon the United Nations to form a commission to study the issue. The commission's task was to find a way of promoting peaceful uses of atomic energy and at the same time eliminate nuclear weapons. In December, 1945 the United States, Britain, and the USSR agreed on the creation of a United Nations Atomic Energy Commission (UNAEC) which requested proposals for control of atomic energy from member nations.

President Truman selected a committee of scientists and governmental officials to study the issue and propose a plan for control. The proposal, the Baruch Plan (presented to the UNAEC in June, 1946), was almost as revolutionary as the discovery of nuclear fission. This plan, introduced by Bernard Baruch (a New York financier) was based on the fact that there was no diplomatic system to protect a nation from nuclear weapons. The only answer to the problem was international control.

The Baruch Plan recommended that all "dangerous" stages of fissionable material production should be entrusted to an international authority. This international body would control all mines, energy-producing piles, and manage all factories producing nuclear fuels. Included in this supervision would be international inspections by a supranational organization. This world agency was to be responsible for the exploitation and development of atomic energy in the interest of all nations.

The USSR and the U.S., however, could not agree on the issue. The Soviet Union considered the Baruch Plan to be a violation of national sovereignty and suggested that control be exercised by national agencies. After two years of discussions and about 200 meetings the UNAEC announced that it had reached a stalemate. In the spring of 1948, the first attempt at international control of atomic energy was suspended. The UN tried to get the talks started again, but in August, 1949 the USSR detonated its first nuclear bomb and the race was on.

Scientist - Policy Maker

The Baruch Plan united U.S. scientists toward a common goal--international control of atomic energy. They supported the plan because it was a product of the scientific methodology. Patient and careful analysis of facts went into the study of the issue; it was not started with a preconceived notion. All facets of the problem were studied and the only logical conclusion was international control. These scientists were certain that this document was a contribution to international politics. They were confident that it would be accepted by all rational people. After all, the plan was scientifically developed.

But they were wrong. The plan was not accepted and U.S. scientists became depressed at this failure. It became obvious that control of atomic energy was not a simple issue. They realized that a new approach was necessary--an approach which considered political road blocks. So many U.S. scientists became involved in forming national security policy. During World War II they were called upon to give recommendations but now the scientists actually became involved in policy making.

U.S. Science Splits

When U.S. governmental officials and scientist started mapping out the role of nuclear weapons in our foreign policy, the scientists became divided. They divided into three groups; each of which attempted to influence U.S. nuclear policy. A summary of these three groups follows.

Control School

A small group of scientists kept hoping for the "Baruch Plan." They were not influential until 1955 at which time a new international agency was founded. A prominent member of this group is Linus Pauling--Nobel Prize Awardee in Chemistry and Peace.

Containment Schools

These other two points of view--represented by a great majority of politically active scientists--believed that military containment of the USSR had to take precedence over international control. However, they disagreed on the amount of containment and subdivided into two groups.

Finite Containment--This group of scientists took the position that it is both feasible and desirable to limit nuclear armament. They advocated the limitation of the arms race (by international agreement) prior to the settlement of political differences and at the same time contain Soviet expansion. Many scientists, including R. Oppenheimer, Hans Bethe, and James B. Conant, supported this position.

Infinite Containment--This group believed that a control system over atomic energy was impossible in the foreseeable future (stated in 1950) and that the arms race would continue. Therefore, they argued, the United States should maintain its lead in the arms race (by developing hydrogen bombs, missiles, and anti-ballistic missiles). They felt that the arms race was unavoidable until political differences could be solved. The champion of this school is Edward Teller--"father of the H-bomb."

Which point of view is most influencial? It is difficult to determine because the political climate varies from time to time. However, all three groups are represented in Washington in positions of policy making and at Congressional hearings. Their testimony is usually a restatement of the three basic positions. Regardless of their position scientists have been influencial in such major governmental departures as: the Baruch Plan; the H-bomb; the development of missiles; and the nuclear test ban treaties of 1963 and 1968.

International Atomic Energy Agency

By December, 1953 both the U.S. and the USSR had successfully tested a new weapon--the hydrogen bomb. This device involves the fusing of lighter nuclei to form a nucleus of a heavier atom. For example, the proton-proton chain reaction probably consists of the following series of steps:

$${}^{1}_{1}\text{H} + {}^{1}_{1}\text{H} \longrightarrow {}^{2}_{1}\text{H} + \text{energy}$$

$${}^{2}_{1}\text{H} + {}^{1}_{1}\text{H} \longrightarrow {}^{3}_{2}\text{He}$$

$${}^{3}_{2}\text{He} + {}^{3}_{2}\text{He} \longrightarrow {}^{4}_{2}\text{He} + 2\,{}^{1}_{1}\text{H}$$

However, the hydrogen bomb explosion probably is due to one or both of the following reactions:

$${}^{6}_{3}\text{Li} + {}^{2}_{1}\text{H} \longrightarrow {}^{4}_{2}\text{He} + {}^{4}_{2}\text{He}$$

(Lithium 6 plus deuterium [or hydrogen 2] yields two helium 4)

or

$${}^{6}_{3}\text{Li} + {}^{1}_{0}\text{n} \longrightarrow {}^{3}_{1}\text{H} + {}^{4}_{2}\text{He}$$

(Lithium 6 plus a neutron yields tritium [or hydrogen 3] plus helium 4)

This hydrogen bomb process--called nuclear fusion--is the reverse of nuclear fission but with fewer limitations.

The size of hydrogen bombs (H-bombs) can be made to be more powerful than atom bombs. A fusion reaction, which is detonated by the heat from a fission reaction, is limited in size only by the amount of fusible material present. The world, which was in possession of a weapon capable of producing explosions equal to millions of tons (megatons) of TNT, was confronted with a bigger problem.

In response to this new situation President Eisenhower proposed (December, 1953) the "Atoms for Peace" program which offered assistance for peaceful uses of atomic energy. In a UN speech, Eisenhower proposed the creation of an international agency to manage a policy of controlled aid on a world-wide basis. This was not a proposal for international control of all aspects of atomic energy but a "first step" in that direction. Nations interested in using atomic energy for peaceful uses were to be given information and materials through this agency. The wall of secrecy surrounding atomic energy was lowered.

On August 8, 1955 the First International Conference on the Peaceful Uses of Atomic Energy was convened at Geneva, Switzerland. This was a monumental occasion for science because it was the first time that scientists and high governmental officials of various countries sat together to work out a world problem. Since then many international meetings have been held but this was the first. The scientist now held a new position, one of international influence.

The delegates to this meeting drew up a constitution for an international atomic energy organization. The UN General Assembly accepted this constitution and established the International Atomic Energy Agency (IAEA) in October, 1956. The IAEA, which began work in October, 1957 in Vienna, consists of a twenty-five nation governing body composed of scientific and diplomatic representatives. Its main function is to supply information and raw materials to nations upon request and to ensure that it is used for peaceful purposes.

The IAEA has encouraged many cooperative ventures in the utilization of atomic energy. The U.S., France, Britain, and the USSR--countries in position of nuclear technology--are helping countries such as India develop a nuclear capacity. The exchange of information and materials is conducted through the IAEA. The system is not perfect but it is a first step. As one author states:

> One of the most significant facts that came out of the atomic meeting in Geneva was the willingness of all nations, including the Soviet Union, to exchange knowledge and experience on the peaceful uses of atomic energy. This in itself promises to go a long way toward the eliminating the danger of an atomic war, as it marks a big step forward toward the eventual international control of atomic energy. (11-5)

Since we have talked about the peaceful uses of atomic energy, let's look at some benefits that can be derived from this new energy source.

Peaceful Uses of Atomic Energy

Nuclear Power Plants

The first full-scale nuclear power plant started operating in December, 1957 at Shippingport, Pennsylvania. Since then numerous reactors have been put into operation and have been providing electrical power in many parts of the world. Nuclear reactors differ in design but they all operate on the same principle--a chain reaction that is controlled.

A chain reaction can be uncontrolled and very rapid (as in the atom bomb) or it can occur at a slow and controlled rate so that some of its energy can be used. In an atom bomb, as we have seen, a critical mass is combined as quickly as possible in order to obtain a rapid chain reaction. But a chain reaction in a nuclear reactor (or pile) is kept under control by the use of control rods. These control rods, usually made of boron or cadmium (excellent neutron absorbers), are withdrawn or inserted into the nuclear pile to increase or decrease the chain reaction.

Many reactors have been built and many more are being designed, but the cost of construction and operation of nuclear power plants has discouraged many countries from using them. The radiation from the chain reaction must be contained within the reactor which requires expensive shielding. In addition, special materials have to be developed to withstand the intense heat and radiation. Protective devices and special water purification methods are also necessary for these facilities. Therefore, power plants using fossil fuels are still favored over nuclear power plants in areas where coal and oil are available.

However, nuclear power plants have a unique characteristic; they are relatively independent of geography. Once a reactor is built it requires only a small volume of fuel--actually only a small fraction of the amount of fossil fuel required--to sustain the chain reaction. This means that atomic energy may permit communities to flourish in regions without sources of coal or oil. As on author states:

> The vast power in the atom can be used to create wealth in wastelands and figureatively stretch the surface of the earth by making places now uninhabitable into fit dwelling places for man. It could be employed to bring to light treasures of mineral wealth now buried in inaccessible places; to irrigate deserts and transform them into blooming gardens; to air-condition vast stretches of the tropics and of the arctic and subarctic continents, thus providing more living space for the increasing world population.
>
> All this is not a mere dream of a present-day Jules Verne. It is a reality. The atomic revolution is actually here, as can be seen by the fact that our leading utilities are investing many millions in the building of atomic power plants.

> Several such plants are already in operation here, in England, and in the Soviet Union, and many more, of gigantic proportions, are now under contruction. (11-6)

Radioisotopes

As we already know, all elements consist of isotopes and some of these isotopes are radioactive. These radioactive atoms, called radioisotopes, produce valuable energy in the form of heat and and other radiation which can be adopted for a variety of scientific, medical, agricultural, and industrial uses.

Where do we get radioisotopes? Some are naturally occurring but most are made by nuclear reactors or atom smashers. During a chain reaction, the uranium or plutonium atoms split and produce many radioactive atoms. These radioactive materials are chemically separated from the reactor debris and packaged for distribution to authorized radioisotope users. Other radioisotopes are created in cyclotrons or other accelerators where high speed protons, deuterons, and other sub-atomic particles are used. Many stable nuclei become radioactive when bombarded by these sub-atomic bullets.

Radioisotopes are useful because they emit radiation at a rate which is essentially independent of all external factors and can be used as a source of radiation or as tracers. They can be used in extremely small quantities--as little as a billionth of a gram can be measured with modern detection equipment--and can be directed to various parts of plants and animal tissue. Let's look at some examples of radioisotopic uses in agiculture, medicine, and industry.

Agriculture

U.S. agriculture loses about twelve billion dollars every year to weeds, insects, and disease and is always looking for ways of reducing this loss. To aid in its study agricultural science is employing radioisotopes in many ways. Radiochemical techniques are being used to study soils, plants, microbes, insects, and farm animals. However, the radioactive isotopes are not used by the farmer but in research laboratories supervised the the U.S. Department of Agriculture and the Atomic Energy Commission. The research is conducted by numerous public and private research institutions. From such research come improved materials and methods which are used on the farm.

Industry

Radioisotopes are so versatile that all their industrial applications could not be covered. However, we can look at two important applications.

Gauging

One of the earliest industrial applications of isotopes was for the process known as "gauging." It is being used by paper, textile, and plastic manufacturers to "feel" the thickness of sheet material being rolled out by machines. There is a good chance that the paper you are holding was was radioisotope-inspected.

The thickness gauge usually consists of a box containing a radioisotope (such as Cesium 137), a radiation detector, and an indicator. As the sheet material passes between the radioactive source and the detector its thickness is checked. If the sheet is too thick the detector receives too little radiation which is indicated on a meter. Workmen adjust the rollers to get the proper thickness of the sheet material. If the sheet is too thin the detector receives too much radiation and again the meter indicates a need for adjustment.

Commercial gauging instruments detect and record variations in sheet materials which are produced at the rate of hundreds of feet per minute. The most modern gauging instruments measure and automatically control the thickness of sheet materials using radioisotopes.

Radiography

Medical and dental x-rays are examples of radiography. However, industrial radiography uses much more energetic x-rays and gamma rays. It is used to check for flaws in metallic welds, to find cracks in automobile pistons, to search for weaknesses in metal plates on ships and submarines, and for many other inspection techniques. The equipment used can be as large as a hospital x-ray machine or as small as a portable television set.

Medicine

Radioisotopes are used as powerful agents for the treatment and prevention of disease. They are used to sterilize drugs and to probe the body and its processes. Isotopes are used for diagnosis, therapy, and teletherapy (deep irradiation therapy). Let's look at some of these tools.

Diagnosis

Arsenic 74. Brain tumors tend to concentrate certain types of ions (charged atoms). If the ions are radioactive it is possible to locate the tumor with a scanning device without using surgery. Arsenic 74 is one radioisotope used for this diagnostic technique. As it decays it emits positrons which also decay, emitting two gamma rays. The scanning device locates the gamma ray source and thus locates the tumor.

Iodine 131. Iodine is a versatile tracer element that is used to determine the volume of blood in the body, liver activity, fat metabolism, thyroid cancer, brain tumors, and the size, shape, and activity of the thyroid gland. Iodine 131 behaves like natural non-radioactive iodine (I-127) in all chemical reactions but it is radioactive. Therefore, I-131 can exist in many different chemical compounds in the body and a detector can tell where it is.

One common diagnostic procedure using I-131 involves the measure of thyroid activity. The patient is given an "iodine 131 cocktail" of radioactive sodium iodide (NaI). After two hours the thyroid gland region is checked for I-131 activity. If the detection indicates an excess of radiation the patient probably has hyperthyroidism (overactive thyroid), and must be treated for this disorder.

Sodium 24. If a sample of saline solution (NaCl) solution is injected into a vein it will circulate through the blood stream. If the sodium chloride solution is "tagged" with sodium 24 the flow of this solution can be traced using a radiation detector. This is the technique used to evaluate the circulation of blood. A sample of Na-24 is injected into a vein in the leg or arm and its rate of circulation determined. If it takes a long time for Na-24 to be detected in other regions of the body poor circulation is indicated. An absence of Na-24 in a part of the body after a period of time indicates an obstruction. The flow of blood through the heart is often traced using this technique.

Therapy

Radioisotopes have an important role in the treatment of disease, in particular cancer. They serve as concentrated sources of radiation and frequently are localized within the diseased cells or organs.

Iodine 131 and Iodine 132. Hyperthyroidism is treated through the use of these isotopes of iodine. Iodine 131 or Iodine 132 in high concentrations is used to irradiate and destroy thyroid gland cells. The reduction of the number of cells results in a decrease in thyroid activity. Iodine 132 with a 2.33 hour half-life is preferred to I-131 which has an 8.1 day half-life. I-132 gives a greater dose of radiation than an equal weight of I-131 and is less hazardous because it is short-lived.

Boron 10. Some organic and inorganic compounds will readily pass into brain tumors but will not pass into normal brain cells. Boron compounds exhibit this property which makes them ideal for certain types of treatments.

In one technique a boron compound is introduced into the body and enters the malignant brain cells. The boron is irradiated with slow neutrons. Boron 10 (often used in control rods) absorbs the slow neutrons and becomes boron 11. The boron 11 decays into alpha particles and lithium isotopes. Since alpha particles have very little penetrating power they irradiate the host cells but do not harm neighboring normal cells.

The disadvantage of using boron compounds is its poisoning affect on body tissues; it can not be used in very large quantities. However, science is looking for harmless boron compounds to be used for this technique.

Phosphorus 32. Polycythemia vera is a chronic blood disease which is characterized by an abnormal increase in red blood cells, an increase in total blood volume, enlargement of the spleen, and a greater tendency toward bleeding.

Medicine does not have a true cure for this malady (ancient medicine used to bleed patients with polycythemia) but phosphorus 32 has been used as an effective therapeutic. This treatment, using sodium radio-phosphate, slows down the formation of red cells and results in the complete remission of all polycythemia symptoms.

However, the treatment is the center of some controversy. The patient's life is lengthened but he usually develops leukemia (a disease of too few red cells). The debated question is, "What caused the leukemia?" One group of doctors says the P-32 was the cause but another group claims the leukemia appeared because the patient's life was prolonged until the leukemia appeared. Nobody knows the answer but many doctors believe that the unproven risk is worth taking to produce the lengthy freedom from the symptoms of polycythemia.

Teletherapy

Many deep x-radiation units (over 200) are being used throughout the United States for the treatment of deep-seated cancers. Most of these units use very intense sources of radiation, usually cobalt 60 or cesium 137. The intensity of these sources are about 1000 curies (the amount of radiation in one gram of radium equals one curies). A tiny cobalt source used in the treatment of cancer gives as much radiation as two pounds of pure radium.

We have discusseed the benefits of atomic energy and radioisotopes, but we have not discussed the risks involved through their use. This is a problem we will consider in the last chapter along with some thoughts about science in general.

CHAPTER XII. ATOMIC ENERGY, SCIENCE, AND THE FUTURE

Atomic Energy

It took aviation forty years to overcome some of its technical difficulties. Early aviation--often financed by military programs--needed years of development and millions of dollars to reach its present status. However, it still has problems because gravity, a phenomenon of nature, is always present to exact its toll whenever man or his machines make mistakes.

The same is true for the utilization of atomic energy; many years will be needed to perfect nuclear technology so that it will be more efficient and less costly. However, nuclear technology is faced with the continual presence of radiation which, like gravity, is always ready to make its presence known. Nuclear technology is dominated by the problem of intense radiation produced in an atomic pile. The behavior of nuclear fuels under radiation, remote-controlled handling and treatment of radioactive wastes, and the protection of the worker and general public are crucial in the development of applications of atomic energy. The increased use of nuclear power is bringing these various difficulties into sharper focus. Let's look at some of

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these difficulties.

Radioactive Wastes

In the years since the discovery of radium (almost 70 years), about seven pounds of this element have been isolated. The radiation due to this powerful radioactive element is small compared to the radiation obtained from a large power reactor which yields radiation equivalent to hundreds of tons of radium. The radioactive by-products of nuclear fission are useful in medicine, agriculture, and industry but we have more radioactive by-products than we can use. This means that we have a problem of excess radioactive material. The big question is, "What do we do with it?" No one knows the answer but it is certain that the waste disposal problem will become more serious.

Radioactivity cannot be neutralized or destroyed by any decontamination process; time is the only factor working against it. In addition, most radioactive by-products cannot be handled by conventional methods, a fact which makes remote-controlled processing of reactor products an important part of nuclear technology. The chemical processing of reactor products is the principal source of radioactive wastes. Special chemical processing plants produce radioactive wastes which usually consist of two solutions: (1) concentrated and extremely radioactive; and (2) dilute but only weakly radioactive.

The highly radioactive solution is stored in watertight underground containers. However, this is only a temporary way of solving the problem because there will eventually be a shortage of storage space. It is hoped that these radioactive residues will be used as a source of industrial heat, but the method for using these materials has not been perfected.

The dilute solutions are too bulky to be stored so they are treated chemically to remove most of the radioactive materials. The resulting solution is further diluted and discharged into nearby bodies of water. Britain has discharged these dilute solutions into the Irish Sea at great distances from land. General use of this method has been criticized because it may eventually lead to some contamination of the ocean.

Another method uses the dilute solution to make concrete blocks which are stored in abandoned mines and tunnels or sunk in deep water. The United States, criticized for this method, has discontinued the dropping of concrete filled barrels into the ocean. It is easy to see that the problem is not easily solved; it is one of the risks for the future.

Radiation and the Body

Early investigators of radioactivity were not aware of its harmful effects until men like Becquerel and Pierre

Curie received severe burns from its radiation. After careful investigation it was found that radioactive materials emit high-energy particles and radiation causing great damage to living tissue. Radiation damages tissue by breaking large molecules or by tearing electrons away from atoms and leaving behind a trail of electrically charged particles (ions). This radiation--ionizing radiation--can cause damage to chromosomes and genes, affect the process of cell division, or cause living cells to die.

Radiation is not detected by any of the natural senses (except in large doses) and has somatic (bodily) and genetic (hereditary) effects on living organisms. Somatic effects and the degree of these effects is dependent upon three factors: (1) the nature of the radiation; (2) the location of the radiation in relation to the exposed organism; and (3) the duration of irradiation.

To judge the danger of radiation all three must be taken into consideration. For example, a dose of radiation which has an even chance of causing death if applied to the whole body would cause no apparent damage if it was confined to one hand or received gradually over a period of twenty years. On the other hand, the ingestion (taken internally) of minute quantities of long-lived radioisotopes--such as radium, plutonium, or strontium 90--could have a harmful effect over a period of years because they become fixed in bones and affect bone marrow. The somatic effects of radiation can often be repaired if discovered soon enough, but it is better to avoid the contamination in the first place.

Genetic effects cannot be repaired, at present. The damage caused to genes in reproductive cells is cumulative and irreversible and leads to mutations. Once a gene has been damaged it cannot be restored to its original structure. Each additional dose of radiation increases the chance for mutations. These mutations do not show themselves in the parent but may arise in later generations. Although we do not definitely know the genetic effect of radiation on man, we cannot assume that this radiation is unimportant.

Protection of Workers and the Public

Radiation has received widespread publicity and arouses much greater fear than other problems created by science. Even without any political problem the fear of radiation is the biggest psychological obstacle to overcome. Industrial development and utilization of fission and fission products cannot afford an accident with nuclear energy. If an accident comparable in magnitude to an airline crash occurred in nuclear technology the development of nuclear energy would be set back several years.

Therefore, safety measures for the nuclear industry are very well-planned and executed. Health protection officers supervise all delicate operations of workers in a reactor area and set time limitations for workers in these active zones. Workers are required to wear photographic film badges (or other similar devices) to record the amount of radiation received by them. They are continually checked for contamination which might adhere to their body or clothing.

The personnel responsible for safety in nuclear technology feel that they cannot be too careful. Experience has shown that accidents result from the absence or failure of individuals to observe precise instructions. As one scientist states:

> It is now recognized that an atomic reactor, even of very low power must be handled with the same discipline as that needed in the navigation of a ship. A system of teamwork with one person clearly in charge at all times is essential, above all for research reactors, where incidents may result from the actions of the experimenters....This brings out the danger of installing a research reactor without being sure of the quality of the team that is to operate it. It is a factor to be considered in providing research reactors to universities or the the developing countries. (12-1)

What about the average citizen? The Atomic Energy Commission and the International Radiological Congress feel that the protection of the public is just as important as that of the worker. These agencies have drawn up strict security rules for the handling of radioactive materials. Under normal operations gaseious and liquid products of nuclear reactors are monitored to insure that the public runs no risk from harmful radiation. But the question remains, "Are the regulations good enough?" No one knows for sure; this is a question that only future research can answer. However, more attention is being given to possible contamination of food from the presence of certain radioisotopes in the air, water, and soil. A large amount of research is being directed toward radioisotopes in man's food chain. Investigators are following the behavior of radicisotopes throughout various biological cycles which are part of man's food supply. This is a start but much more work has to be done in this area.

The Nth Nuclear Power

Before the atomic age, military importance was determined by such factors as the strategic situation (natural geographic protection is one), the population, and the industrial potential. With the development of nuclear energy these factors have become secondary to the possession and delivery of atomic weapons. The nuclear potential of a nation is one of the key elements of its international influence. Plutonium, not gold, is the dream of the modern alchemist; this substance is a measure of the strength and wealth of a nation.

It is easy to see that the development of atomic energy has had economic, sociological, and philosophical implications for society. However, the political problem is the most alarming. Nuclear weapons, which can be delivered by ballistic missiles and fires from land, air, or under the sea, might start an atomic war without the aggressor being known. This may seem impossible but as the number of countries possessing nuclear weapons increases the chance for this event becomes more real.

The United States was the first to possess nuclear weapons, followed by Britain and the Soviet Union. The U.S. monopoly on nuclear weapons lasted only four years (we had hoped for fifteen or twenty). In 1960, France became the fourth power with nuclear weapons and has since been followed by China. Scientists have predicted that Sweden and India will have nuclear weapons by 1970. Even tiny Switzerland has not ruled out the necessity of nuclear weapons to insure her neutrality (a referendum in March, 1962 rejected by a two-thirds majority a proposal to prohibit the storage, manufacture, and use of nuclear weapons). Which nation will be the seventh, eighth, ninth, or the Nth nuclear power? Nobody knowns. One scientist, representing the thought of many, states:

> The controlled aid policy ["atoms for peace"] is only a temporary and not very effective palliative [cure]; in the absence of real world-wide control of peaceful development of atomic energy, the attempts by the advanced countries to impose safeguards as a condition of their help to the less-developed countries will probably always be inefficient in the long run. (12-2)

and he further states:

> The great problem of our time is not the useful application of atomic energy but the dilemma posed by the existence of nuclear weapons.
>
> The principal characteristics of the atomic problem is that in many ways it has outrun human comprehension and control. The problems raised, the orders of magnitude involved and the consequences to which it could lead are no longer on the human scale. The solutions so far proposed bear this out, whether in the matter of atomic secrecy--which has not survived the march of technical advance--or in the question of the control of the bomb, so often discussed yet never really brought into being. Only a completely international solution seems valid, for the whole problem--from its foundation to its furthermost extensions must be tackled as an entity. (12-3)

and finally:

> Faced with the atomic challenge, man must find the way to banish forever the threat of war. (12-4)

A statement by Secretary of War Henry Stimson best summarizes the peril and promise of atomic energy. This statement, written in 1946, is pertinent today. He wrote:

> The development of atomic energy holds great, but as yet unexploited, promise for the well-being of civilization. Whether this promise will be realized depends on whether the danger of swift and unprecedented destruction can be removed from the earth. Whether it is removed depends on whether we and other nations move firmly, quickly, and with frank transparency of purpose toward the goal of uniting all men of good will against the appalling threat to man's very existence. The focus of the problem does not lie in the atom; it resides in the hearts of men. (12-5)

Science

In the last few years numerous books and articles have appeared relating today's scientist and his place in society. These studies--often uncomplimentary to science--indicate that serious thought is being given to the scientist's position in society at a time when he is playing his greatest role in human affairs. The consensus of most of these writers is that the consequences of science have become so great that new roles and responsibilities will be placed upon the scientist by society.

We do not know exactly what responsibilities scientists had in earlier times but we do believe that they did have some influence. The early waves of science--Egyptian and Mesopotamian--contributed some mathematics, astronomy, and rudimentary explanations of the universe. These early scientists were responsible for the administration of many public affairs but their influence on society was primarily based on their interpretation of magical and supernatural signs.

The Greeks, having greater freedom of thought and travel than their predecessors, were able to develop and perpetuate a natural philosophy which gave rise to speculative science. The natural philosopher, who was held in high esteem, did not see much relation between his speculations and the daily needs of society. In fact, practical knowledge was degraded by most educated Greeks who felt that only abstract thinking produced the "ultimate knowledge." According to an ancient legend, a student at Plato's Academy asking the question, "What is the use of this?", usually met with immediate expulsion.

The knowledge of early Greece did not physically change Greek society or really have an effect on society for many years. But this knowledge was preserved by the efforts of the Arabs who wanted to accumulate all scientific knowledge and make it part of their empire. They preserved this knowledge until it was translated into Latin and revived by the work of Thomas Acquinas in theology and Roger Bacon in natural philosophy. Later, men such as Copernicus and Galileo put Roger Bacon's reasoning to work and established the basis for our experimental sciences.

During the Renaissance men of science started to find contradictions in the work of their predecessors. They looked at the contributions of previous generations, in particular Aristotle's science, and by careful examination disproved many of the "absolute truths." Science was mostly theoretical in those days and was essentially separate from technology. The work of Kepler, Newton, and Descartes provoked further thinking but did not have any enormous physical impact on society. The impact or influence of their work was translated into useful applications later.

Around the 1780's when the industrial potential of the steam engine was recognized, the practical value of modern science seemed very slight. Science was almost entirely an intellectual effort to understand the physical universe. The advancement of science was the work of individuals who made scientific work their personal responsibility. The great achievements of research during this time were the work of the "great amateurs" who were aided occasionally by the state and other public bodies.

Science was regarded as a discipline of intellectual activity concerned with the attainment of truth about nature. Technical applications of knowledge were dependent upon activities which were considered to be quite distinct from those involved in the pursuit of truth. Scientists performed their work in an atmosphere almost independent of society. In the 18th Century European scientists, who were almost completely independent of state politics, began to consider science as being "amoral" and themselves as "autonomous seekers of truth."

In the 19th Century, however, science was revealed to be applicable to technical, industrial, and social necessities. Politicians, businessmen, etc. saw science as a seeker of truth and a means of achieving personal and political power. Science began to have much closer relations with society. In the process, science and technology became more closely associated; scientific applications became more practical and technical craftsmanship became more scientific.

Scientific research brought into existence the need for research instruments and machines which were developed by skilled craftsmen. Thus, the progress of science and the advancement of technology became inseparable goals; they were now interrelated and interdependent.

Furthermore, science ceased to be the concern of a small number of devoted men with private means of support. Science and society now needed a large number of scientists. As the ranks of scientific research increased the members of this activity became more and more specialized. In addition, scientists became more dependent upon industrial and academic institutions (scientific societies, universities) for financial support.

During this period of time, national governments began to interest scientists in problems of national interest and concern. First in France, then England and Germany, science began to be considered as a part of the natural resources and was called upon to serve and rescue the national state. The United States lagged behind the other nations. For example, between 1863 and 1913 the War Department consulted the National Academy of Sciences (established in 1863) on only five matters:

1. On the question of Tests for the Purity of Whiskey.
2. On the Preservation of Paint on Army Knapsacks.
3. On the Galvanic Action from Association of Zinc and Iron.

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4. On Question of Meteorlogical Science and Its Applications.
5. On Exploration of the Yellowstone.

Times have changed! Since World War I and in particular since the start of the Atomic Age, science has been given an increasingly prominent position in our nation. Today, government advisory groups include the National Academy of Sciences--the National Research Council, the National Science Foundation, the Office of Science and Technology, the President's Science Advisory Committee, the National Aercnautic and Space Council, and many others. All these organizations, collectively called the "Scientific Establishment," perform valuable services and contribute much toward fostering the growth of science and our nation. But there is concern among many in society that the work of these groups will not be enough to organize science to meet many of the large-scale problems of the future. Many of these problems have been the result of scientific advances. As Dr. Seaborg(chairman of the AEC) states:

> Studying the development of theory and the course of applied science, an interesting conclusion can be drawn: that the time between the birth of a scientific theory and the physical application of some aspect of that theory is rapidly diminishing....while knowledge is being disseminated more widely and effectively, it is also being applied much more rapidly. (12-6)

and further:

> ...when a scientist comes up with an important theory today he is more likely to see it destroyed or used fruitfully within his lifetime. If it involves something which can have a beneficial effect on man he will probably witness the good he has produced and in all likelihood receive rewards for it. If it involves something which can result in good or ill for man he faces the possibility of seeing it used either way, even though his intention in discovering and revealing the knowledge was simply the finding and revelation of truth (for centuries the essential,....purpose of science). (12-7)

This leads to the question, "What is the role of science and scientists in society today?" Many argue that science is "amoral" and that scientists should remain "neutral." However, others argue that scientific and technological developments are presenting us with many consequences that cannot be ignored by the scientist. For example, the benefits of nuclear energy have associated risks which science and society cannot ignore. In addition, increased population, air and water pollution, plus other social and economic problems must be faced. Some scientists predict that the control of hereditary and personality traits by adjusting our genetic code is a problem that must soon be solved. What is the role? One historian states:

> Scientists must become increasingly aware of the complexity and intimacy of science's relationship to its total context [society]. (12-8)

and

> The cultural support that science enjoys today rests more on fear of foreign enemies and of disease than upon understanding, and fear may not be a healthy and lasting foundation. Science needs its statesman, and statesmanship demands the long view. Those responsible for statesmanship of science must develop a scientific understanding of science itself. We must learn to think about science in new ways unless we intend to leave the future of science to chance. (12-9)

Dr. Seaborg, who agrees with these vital points, feels that the social responsibility of science imposes upon the scientist two burdens.

> First, scientists must attempt to broaden their horizons both scientifically and in the affairs of society.... he must enter the interdisciplinary world in which we all live and try to contribute to it. (12-10)

> Secondly, the scientists today must become more articulate within the scientific community and as a citizen if he is to assume any leadership or influence the course of human events which could result from his scientific work. (12-11)

and finally,

> Basically, the findings of science may be value-free, but the impetus of science,...,is derived from human values as well as man's basic curiosity, and while we can talk of science being neutral, it is impossible today to act as if it were such. Most of today's scientific truths do have consequences--and they are consequences we must be prepared to face....most of today's scientists

> will be alive to see their theoretical and experimental work applied in some manner or other. And whether or not they claim neutrality, the world is going to turn to them for some understanding and guidance in using their work. (12-12)

During this unit you were asked to think about changing events. If you could go back in time where would you like to go and what event would you try to change? There is no one answer so think about it carefully. In addition, when would you have liked to have lived? During Ancient Greece? The Renaissance? The 19th Century? Or today?

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CHAPTER I. TEACHER'S GUIDE

The purpose of Chapter I is to give the student an overview of the unit and to set the basis for further study. The chapter presents questions that will be answered by later readings and discussions. The emphasis should be on arousing interest that will lead to possible answers later.

Things to Consider	Teaching Suggestions
1. Many regions of the world are using electricity produced by nuclear energy power reactors.	1. Start with the movie: Nuclear Energy Goes Rural.
2. Nuclear power plants are similar to a conventional power plant. Each type uses steam to drive a generator which produces electricity. a. Fossil fuels produce heat by combustion. b. Nuclear fuels produce heat by fission.	2. Slide I-1. Types of Nuclear Power Plants. Show the students that the only difference is the reactor and heat exchange section.
3. Nuclear energy will replace fossil fuels in the future.	3. Slide I-2. Energy Patterns Today. Question: When will nuclear fuels be used to a greater percent than are used today?
4. The nucleus of an atom is the most concentrated source of energy known.	4. Slide I-3. Comparison of Uranium to an Equivalent Amount of Coal. Slide I-4. Energy Comparison. Discuss the advantage of transporting nuclear fuels.

Things to Consider	Teaching Suggestions
5. A unique characteristic of a nuclear reactor is its geographic independence. a. Nuclear energy may permit cities to be built in regions remote from existing sources of power. b. Electricity is being produced in regions where agricultural and industrial opportunities were previously limited.	5. Slide I-5. Nuclear Power Plants in the United States. Discuss the geographic distribution of nuclear reactors at present. Question: Where can other nuclear reactors be useful?
6. The study of nuclear energy and its social implications are excellent opportunities to look at the relationship between science and society.	6. Discuss the plan to use the development of atomic energy as a means to study the relationship between science and society.
7. The development of atomic energy is due to the work of scientists from many countries.	7. Questions: Who were responsible for the development of atomic energy? When did these investigations begin?
8. Scientific investigation and utilization of nuclear energy has political, sociological, and biological implications for society.	8. Question: What implications does atomic energy have for society? List the categories and the implications.
9. The relationship between scientists and society has varied throughout history; he has been viewed differently by different societies.	9. Slide I-6. Time Chart of Main Periods of Science. Introduce the periods to be studied and mention the scientists of the period.

Things to Consider	Teaching Suggestions
10. The scientist of today is not more intelligent or imaginative than earlier scientists; he possesses a greater amount of knowledge.	10. Question: What advantage does a scientist of today have over his predecessors?
11. All scientists have a common goal: make nature more understandable.	11. Question: What is the primary goal of all scientists?
12. There is not one but many scientific methods; no method guarantees success. a. Beliefs related to the nature of matter have been based upon direct or indirect observations. b. Scientists make generalizations about nature. c. Although some generalizations made by scientists have been found to be incorrect they have contributed to the total body of scientific knowledge.	12. Question: What is the scientific method? Discuss the methods of science as an introduction. Ask the sutdents to keep the statements under this topic in mind when they read later chapters. Use Thales' theory about water being a primordial substance as an example.
13. It is difficult to divide scientists into separate categories; their activities are interrelated and interdependent. a. Pure science has been considered as a quest for knowledge to satisfy curiosity. b. Applied science has been considered to be an application of pure science to a particular problem.	13. Question: What are the categories of scientists? What is the difference between them? Emphasize the interrelationship between the two aspects of science.

Things to Consider	Teaching Suggestions
14. The scientist and the concept of matter have undergone stages of development; this development has tended to follow a cyclic pattern.	14. Slide I-7. Chart of Historical Cycles. Call the students' attention to the cyclic pattern of science and sculpture.

CHAPTER II. TEACHER'S GUIDE

Chapter II is intended to bring to the attention of the student the idea that science is an organized social activity that started with the dawn of early man. It is important to point out that science is not described by any one method or any specific body of knowledge. This chapter permits tremendous latitude in citing examples of early science; there are many examples available.

Things to Consider	Teaching Suggestions
1. Science, which may be defined as an organized social activity, has its roots in the spiritual and technical traditions.	1. Question: How may science be defined?
a. The spiritual tradition involved human aspirations and ideas. b. The technical tradition consisted of practical crafts and skills.	a. Slide II-1. Cave Drawings - Hunting Season Worship. b. Slide II-2. Early Farming Tools. Slide II-3. Pottery Tray (for husking grain).
2. The practice of science dates back to early antiquity.	2. Call attention to the evidence that will be presented during this chapter to help to show that man has been making and recording observations for centuries. The cave drawing is one example.
a. Man has been making observations since pre-historic times. b. Early scientists employed the concept of supernatural power to explain many phenomena.	
3. Early societies developed along rivers that supplied fertile land to support large communities.	3. Slide II-4. Map of the Fertile Crescent. Slide II-5. Map of the Nile River Valley. Discuss the geographic location of these two early civilizations.

Things to Consider	Teaching Suggestions
4. The work of early craftsmen has left a record of some of early man's accomplishments.	4. Slide II-6. Early Mesopotamian Pottery. Slide II-7. "Scarlet Ware" Vase. Slide II-8. Early Mesopotamian Chariot.
5. Natural phenomena has an influence on the lives of people and how they think.	5. Contrast the influence environment had on the Egyptians and Mesopotamians.
6. The Egyptians considered the future to be certain.	6. Slide II-9. The Universe as Viewed by the Egyptians.
a. They considered the universe to be a large box.	a. Discuss the Egyptian concept of the universe as it relates to the Nile River.
b. Their science was practical applied science or technology.	
7. Mesopotamians considered the future to be uncertain.	7. Slide II-10. The Universe as Viewed by the Chaldeans (Mesopotamians). Discuss the Mesopotamian concept of the universe and how it relates to the Tigris-Euphrates River environment.
a. They viewed the universe as a domed vault b. Mesopotamians practiced predictive science; they resorted to astrology and examination of sacrificial livers. c. Calendar making was delegated to a select group of men called "scribes."	
8. Early civilization contributed much to the advance of science and civilization.	8. Question: What were the contributions of the Egyptian and Mesopotamian civilizations to the advance of science and man?
a. They supplied tools. b. They began mathematics.	

Things to Consider	Teaching Suggestions
c. They started the science called astronomy. d. They promoted the organized practice of medicine and surgery.	
9. The invention of writing was a foundation of science; man could record his observations in an organized form.	9. Slide II-11. Cuneform Writing. Slide II-12. Mesopotamian Scribes. Slide II-13. Egyptian Hieroglyphics. Slide II-14. Egyptian Scribes.
10. Egyptians and Mesopotamians were the earliest toolmakers in recorded history.	10. Slide II-15. Gold and Stone Sculpture. Slide II-16. Mesopotamian Warrior Helmet. Slide II-17. Copper Cooking Ware. Slide II-18. Egyptian Glass.
11. Throughout history two methods have been utilized to treat illnesses: a. Healing by mental means such as magic spells and incantations; and b. Healing by practical means such as drugs, baths, diets, and surgery.	11. Discuss and contrast the use of magic versus the use of science in the treatment of disease.
12. Science is directed by reason and corrected by observations; magic is taught by mysterious initiations and is usually explained by myth.	12. Introduce the difference between science and magic using early practices in medicine as examples.
a. Early Egyptians excelled in physical medicine which was a practical applied science.	a. Slide II-19. Egyptian Medicine (also refer to Slide II-13. Hieroglyphics).

Things to Consider	Teaching Suggestions
b. Later Egyptian medicine was based on myth and superstition.	
c. Mesopotamian medicine excelled in mental medicine which was based on superstition and myth.	c. Slide II-20. Mesopotamian Medicine. Slide II-21. Copper Replica of Sacrificial Liver.
13. Early scientists employed the concept of supernatural powers to explain many phenomena; they used the "demon theory of disease" to explain illness.	13. Discuss the use of magic exhortations and the use of harsh drugs to expel the evil spirits of illness.
14. The Egyptians and Mesopotamians made calendars for predicting dates of crop planting and festivals. This led to a close observation of the heavens. a. Astrology predicts events based on the movement of heavenly bodies. b. Astronomy is the study of the stars.	14. Slide II-22. Days of the Week. Discuss how the spiritual beliefs of the Mesopotamians led to the seven-day week. Slide II-23. Egyptian Merkhet. Question: How much would we know about the heavens if we did not have telescopes?
15. Both civilizations contributed to the development of mathematics. a. The Egyptians were leaders in surveying and architecture. b. The Mesopotamians excelled in mathematical calculations. They knew the "Pythagorean relationship."	15. Slide II-24. Egyptian Scribes. Slide II-25. Egyptian Pyramids. Slide II-26. Artist's Conception of the Pyramids.

CHAPTER III. TEACHER'S GUIDE

Chapter III considers Greek science as an extension of earlier scientific activity and the predecessor of modern science. This chapter considers the change in science from empirical to theoretical and back to empirical. The change in emphasis in Greek science took place over a period of about 800 years and was influenced by social conditions. This chapter is also used to introduce the question about the nature of matter and the concept of the atom.

Things to Consider	Teaching Suggestions
1. Theoretical science could grow in Ancient Greece because of a simple political structure at that time and commercial sea travel which aided in the gathering of ideas.	1. Slide III-1. Map of Ancient Greece. Discuss the geographic position of Greece and its relation to Egypt and Mesopotamia. Question: Why were the Greeks able to speculate and not other people of this time?
a. The Greeks humanized their gods.	
b. The Greeks had alphabetic writing that was easier to understand than other writings at that time.	
c. The Greeks had a well established commercial trade.	c. Slide III-2. Greek Olive Groves.
d. The Greek civilization was divided into a series of city-states which had leisure and labor classes.	d. Slide III-3. Greek Opinion Poll. Slide III-4. Athenian School.
2. Science in Ancient Greece was primarily an intellectual activity of the leisure class.	2. Question: Who engaged in the intellectual activity called science?

Things to Consider	Teaching Suggestions
a. One reason for the absence of experimentation during this time was the dislike of manual labor by the leisure class.	a. Slide III-5. Greek Architecture. Discuss the separation of the Greek community into two distinct classes.
3. Greek science was speculative and theoretical while Egyptian and Mesopotamian science was empirical.	3. Question: What was the difference between Greek and earlier sciences?
a. Empirical science is based on direct and indirect observations.	a. Question: What is empirical science and how does it differ from theoretical science?
b. Greek science was the forerunner of many modern sciences.	b. Call the students' attention to the fact that Greek science provided a working base for many modern sciences.
4. The question, "What is the nature of matter?" has been explained by two opposing points of view.	4. Briefly discuss the question of the nature of matter. Use it as an introduction to Greek speculative science.
a. Matter is continuous. b. Matter is discontinuous.	
5. The first period of the Greek intellectual tradition became distinctly recognizable about 600 B.C.; its origin is unknown.	5. Repeat Slide III-1, to show the locality of the first known scientific center of Greece.
a. The beginning of Greek science is usually traced to Thales, who believed that water was the primordial substance.	a. Emphasize the fact that Thales' generalization was based on an incorrect conclusion of direct observations and that although it was incorrect it stimulated thinking.

Things to Consider	Teaching Suggestions
b. Other Greek scientists held different views which were later combined into a theory of elements.	b. Use this to amplify 5a.
1) Anaximander.	1) Matter is made of an unidentifiable primary substance.
2) Anaximenes.	2) Air is the primordial substance.
3) Empedocles.	3) Matter is composed of four elements: air, water, earth, and fire.
4) Leucippus and Democritus.	4) All matter consists of atoms.
6. The second period of Greek science was marked by the influence of Socrates, Plato, and Aristotle.	6. Call attention to the change in location of Greek science (from Miletus to Athens) and how science became less emphasized.
a. Socrates rejected natural philosophy (science) and emphasized the need for concern with problems of ethics and politics.	a. Discuss the change in attitude of the Athenians after the Peloponnesian War (431-404 B.C.).
b. Early Greek science was influenced by Plato who believed that ideas should be based on images created in the mind rather than on observations made with the senses.	b. Emphasize Plato's belief in mental images; it is important because it turns Greek science away from observation of nature.
c. Plato's four elements were geometric figures constructed from a unit triangle.	c. Slide III-6. Plato's Elements (air-octrahedra, water-eicosahedra, earth-cubes, fire-tetrahedra, and quintessence-dodecahedron.

Things to Consider	Teaching Suggestions
d. Plato and Aristotle abandoned the effort to explain natural phenomena by physical forces exclusively; this was detrimental to the advance of physical science.	d. Again emphasize the turn of Greek science toward greater speculation.
e. The four elements, according to Aristotle, are properties or qualities rather than substances; one element could be changed into another by changing its properties.	e. Slide III-7. Aristotle's Four Elements and Four Qualities. Call attention to the elements of Aristotle; they are considered mixtures and compounds today.
f. The Greeks believed that the earth was a sphere and was at the center of the solar system.	f. Slide III-8. The Universe as Viewed by the Greeks.
7. The third period of Greek science was marked by a shift to empirical science.	7. Discuss the turn of Greek science from theoretical back to empirical.
a. The establishment of Alexandria and the collection of data during Alexander's conquest of Asia Minor provided the means (or stimulus) for the change to empirical science.	a. Question: What happened to Greek science as its center of activity changed from Athens to Alexandria? Slide III-9. Map of Alexandrian Empire.
b. The empirical science of Alexandria was evidenced by the rise of a group of well-trained engineers (Archimedes, Philo, and Hero).	b. Give examples of some accomplishments of Alexandrian engineering, such as Archemede's screw-pump, or Hero's steam engine.

Things to Consider	Teaching Suggestions
8. The close of the third period, which preceded the Roman conquest of Egypt, was marked by a stagnation of Greek Alexandrian science. a. External influences became less favorable. b. Scientific pride gave way to criticism, caustic comments, and a review of past triumphs. c. Horoscoping was developed and practiced at this time.	8. Emphasize the loss of vitality in Alexandrian science. Discuss some of the external factors that contributed to the stagnation of this science. Slide III-10. Ptolemy's Epicycles. Slide III-11. The Universe at the Close of Alexandrian Science.

CHAPTER IV. TEACHER'S GUIDE

The rise of the Roman Empire marks the start of the floundering of science. This chapter considers three social attitudes and interests toward science. The Roman, Arabian, and Christian interest in science represents three distinct frames of reference for science. Each social group had distinctly different interests in science. They also emphasized science differently. The purpose of Chapter IV is to show these three distinct cultures and their use of science. The influence of Greek scientific thinking during these 1500 years (100 B.C. to A.D. 1400) should be emphasized; it was the main scientific chain of thought during this period.

Things to Consider	Teaching Suggestions
1. The era of Greek influence was followed by about 1500 years during which time science floundered; the ideas of the Greeks controlled thinking during this period of time.	1. Discuss the control of thinking in matters of science. Use Aristotle's concept of matter as an example. He believed that matter was continuous and infinitely divisible.
2. The Romans failed to carry on the Greek scientific tradition. a. The Romans were interested in the application of science. b. The Romans enjoyed less freedom than the Greeks; senators were forbidden to become involved in commerce.	2. Slide IV-1. Map of the Roman Empire at its Greatest Extent. Compare the thoughts of the Greeks with those of the Romans; in particular, freedom for the leisure class.
3. The Romans are known for their engineering and practical scientific achievements.	3. Slide IV-2. Roman Arch Bridge in Spain. Slide IV-3. Roman Aqueduct in France. Slide IV-4. Roman Medical Instruments.

Things to Consider	Teaching Suggestions
a. They built roads and aqueducts. b. The Romans devised the Julian Calendar using Greek knowledge of astronomy. c. The Romans built hospitals but staffed them with Greek physicians.	
4. The Romans did not add a great deal to science; they had an unintentional negative influence on science.	4. Discuss and emphasize the difference in interest between the Romans and the Greeks.
a. The Romans encouraged horoscoping.	
b. Alchemy was derived from Alexandrian Greek science.	b. Slide IV-5. The Paths of Alchemy (Map). Indicate the travels of alchemy toward the east and west. Call attention to the fact that alchemists preserved experimentation.
5. Alchemy, which continued until the 1800's, was the result of the integration of three important factors:	5. Slide IV-6. The Equipment of the Alchemist. Slide IV-7. Arabian Alchemy. Slide IV-8. Alchemy in the Middle Ages.
a. Egyptian craftsmanship was the practical aspect; b. Aristotle's basic view of transmutation of elements provided the theoretical aspect; and c. Stoic and Neo-Platonic philosophies provided the spiritual aspect.	

Things to Consider	Teaching Suggestions
6. Arabian scientists were patronized by Arab rulers who wanted to accumulate all scientific knowledge in the Islamic Empire.	6. Slide IV-9. Map of the Moslem World. Discuss the migration of Arabian science from the east to the west (Spain).
7. Arab scientists (A.D. 900) made a great contribution to science through their translations and summaries of the work of Greek scientists.	7. Slide IV-10. Moslem Scientists. Discuss the work of Arab scientists and their use of the new mathematics--algebra. Compare the work of the Greeks and the Arabs. Question: How did the Arabs contribute to the advance of science?
a. Many classical books were translated from Arabic into Latin.	
b. The Arabs did a great service to science by providing a storehouse for scientific knowledge.	
c. The Arabs introduced "Arabic numerals" (12th Century) which they passed on to the Europeans.	c. Emphasize the service performed by the Arabs; they acted as disseminators of scientific knowledge.
8. The interaction between science and Christianity has varied through the centuries.	8. Stress this point; it is very important.
a. Early Christianity was indifferent to nature and attracted many gifted men to religious studies.	a. Slide IV-11. An Early Christian Scientist. Discuss the attraction of gifted men to the study of religion, causing a decrease in the study of nature.
b. The 12th Century marked a change in the Christian attitude toward science.	b. Slide IV-12. Early Christian Scientists.

Things to Consider	Teaching Suggestions
c. St. Francis of Assisi expressed the view that matter was worth studying for its own sake. d. Medieval scientists did not contribute much new insight to the study of nature; they were usually members of religious orders that were advocates of the ideas of Aristotle and Plato.	c. & d. Discuss the significance of the views of Francis of Assisi, Albert Magnus, and Thomas Acquinas. These views had a strong influence on science during the next 300 years.
e. Roger Bacon's natural theology changed the role of man from a passive recipient of spiritual messages through natural phenomena to active seekers of an understanding of the Divine nature; natural theology was a major foundation of western science.	e. Call the students' attention to the change in attitude of the Christians. Discuss the Cathar heresy and its possible influence on this change in attitude. Slide IV-13. The Hill of Knowledge. Discuss the relative importance placed on theology during the Middle Ages.
9. Printing using moveable type (invented by Coster and Gutenberg in 1450) had a tremendous influence on the development of science; it improved the dissemination of scientific information.	9. Slide IV-14. Printing Press. Using this slide of an 1812 printing press discuss the advantage of using moveable type rather than block type.

CHAPTER V. TEACHER'S GUIDE

Chapter V considers the rejuvenation of science during the 16th and 17th Centuries. It looks at motives that stimulated society to promote science. The university and scientific societies provided conducive atmospheres for science during this period of strong church domination (Catholic and Protestant). This period ended with greater freedom of thought for the individual and was marked by an abundance of gifted amateur scientists. The change in the methods used by scientists is considered through the discussion of four contributors to science: Francis Bacon; Descartes; Galileo; and Newton.

Things to Consider	Teaching Suggestions
1. Until the 17th Century scientific and social thought was dominated by the ideas of the Greeks. a. The Greeks believed that everything in the universe was absolute and unchanging. b. The Greeks believed that the earth did not move and was at the center of the universe. c. Aristotle's ideas were accepted and protected by religious authority.	1. Tie chapters III and IV with this chapter by reviewing some of the beliefs held by the Greeks. Use Aristotle's concept of the nature of matter as an example.
2. The academy, lyceum, university, and scientific society were centers of scientific activity with the university leading during the late Middle Ages.	2. Slide V-1. *Trinity College, Cambridge.*

Things to Consider	Teaching Suggestions
a. The university and its educational tradition was the springboard for the rebirth of science.	a. & b. Stress the service performed by the university and the scientific society.
b. Scientific societies filled a need for meeting places where science could exist in a sympathetic atmosphere.	
3. During the Middle Ages, European scientists were inspired to utilize scientific inquiry for various purposes.	3.
a. Economic motives were responsible for the support of studies of navigation and mining.	a. Slide V-2. Journeys of Exploration and Commerce. Slide V-3. 16th Century Water Pump. Slide V-4. Greenwich Observatory.
b. Religious motives resulted in the use of science to correct the Julian Calendar.	b. Slide V-5. Calendar Making.
c. Practical motives influenced studies in medicine, military weapons, and fortifications.	c. Slide V-6. Balistics Diagram.
d. Religious motives led to a renewed and disinterested desire to know the works of the Creator.	d. Slide V-7. Renaissance Scientist. Slide V-8. Globe of the World in 1492.
4. Empirical science requires the support of financial benefactors; it first flourished in Italy, France, England, and other parts of western Europe where a strong economic structure existed.	4. Question: Why was empirical science first able to flourish in western Europe and not in other cultures?

Things to Consider	Teaching Suggestions
5. Prior to the 17th Century most scientists developed generalizations from mental images and applied them to natural phenomena by deduction; they followed the deductive approach practiced by Aristotle.	5. Discuss the method used before the 17th Century and compare this method with the inductive approach.
6. Francis Bacon advocated experimentation in science and believed that observation and tabulation were important aspects of scientific investigation. a. He was not a scientist but his writings had great influence on science.	6. Slide V-9. Sir Francis Bacon. Compare deduction with induction. Deduction is the method of going from generalizations to specifics. Induction is the method of going from specifics to generalizations.
7. Descartes method of study was contrary to Bacon's approach. a. Bacon advocated experimentation and induction. b. Descartes preferred mathematical reasoning and deduction.	7. Continue the comparison of induction and deduction.
8. Galileo presented ideas that cast doubt on Aristotle's works as the final authority in science.	8. Slide V-10. Galileo Galilei.
a. Galileo's experimentation led him to doubt Aristotle's falling body theory. b. Galileo developed telescopes to study the heavens and again found Aristotle in error.	a. Slide V-11. Chapel at Pisa. Slide V-12. Pendulum Clock. b. Slide V-13. Galileo's Telescopes.

Things to Consider	Teaching Suggestions
9. At times, society has been intolerant of science and scientists. Condemnation of Galileo for defending the heliocentric concept of the universe is an example of intolerance by authority.	9. Slide V-14. *Ptolemy System.* Slide V-15. *Copernican System.* Slide V-16. *Monument to Galileo.*
10. Newton integrated the experimental induction of Bacon with the mathematical deduction of Descartes; his scientific style is looked upon as the approach that changed ancient empirical science into modern empirical science.	10. Slide V-17. *Newton's Room.* Slide V-18. *Discovery of the Spectrum.* Slide V-19. *Newton's Telescope.* Slide V-20. *Portrait of Newton.* Slide V-21. *Blake's View of Newton.* Slide V-22. *Newton's Tomb.*

CHAPTER VI. TEACHER'S GUIDE

The purpose of this chapter is to bring the students to the present (or at least to the 20th Century). Attention should be given to change in the emphasis of science, the change from amateur to professional scientist, and the change from privately to nationally financed science. Special attention should be placed on the applied science of the United States and its service to society. The rise and fall of German science presents an excellent opportunity to study favorable and unfavorable atmospheres for scientific activity.

Things to Consider	Teaching Suggestions
1. Science has been developing for centuries but it was not until the middle of the 19th Century that it began to have practical and therefore economic consequences for society.	1. Summarize the history of of science before 1800 to give the student a starting point for this chapter.
a. The first half of the 18th Century was a twilight period in the history of science.	a. Slide VI-1. Marine Chronometer. Slide VI-2. Newcomen Steam Engine
b. In England scientific interest changed from problems of navigation to questions of agricultural reform and the industrial revolution.	b. Slide VI-3. English Industrial Town.
c. In France, scholars were preoccupied with the conditions leading to the French Revolution.	c. Slide VI-4. French Lecture Room.

Things to Consider	Teaching Suggestions'
2. The social background of scientists in England changed from country gentlemen to descendents of the trade tradition. a. English science became decentralized. b. English science was given national support after the start of World War I; Britain has maintained a staff of well-trained scientists since that time.	2. and 3. Compare British and French science. Call attention to the division of scientific activity along national lines.
3. French science has had national support since the 1600's. a. France was the first country to consider science a national asset. b. Most French scientists were members of the lawyer or civil servant class of peoples. c. French science became centralized at the time of Napoleon and has remained that way.	
4. Germany was the first country to develop industrial and political strength by institutionalizing science at the national level.	4., 5., and 6. Discuss the rise and decline of German science and the social (political) conditions of the years between 1870 and 1940.
5. 16th, 17th, and 18th Century German science was divided because Germany was divided into many principalities; after the unification of Germany by Bismark, German science became an ever increasing national resource.	

Things to Consider	Teaching Suggestions
6. The rise of National Socialism in Germany led to the weakening of German science; theoretical science declined rapidly after Hitler came to power.	
7. In this century, many countries have realized the significance of science and as a consequence have encouraged the pursuit of science.	7. Emphasize the increased support of science by national governments.
8. United States science, which was derived from the British scientific tradition, has been primarily utilitarian in character. a. Thomas Jefferson promoted national science, but was unsuccessful in establishing a national scientific institute. b. The Smithsonian Institute was founded by Congress with funds provided by an English nobleman. c. The U.S. government gave assistance to industry and agriculture following the Civil War; the attitude of the government changed from "states rights" to "general welfare." d. Science contributed to the military projects of World War I, but was ignored during the 1930's and early 1940's.	8. Slide VI-5. Franklin Experiment. Slide VI-6. Newburgh Fossil Excavation. Slide VI-7. Breechloading Gun. Slide VI-8. Gatling Gun. Slide VI-9. Self-Propelled Steam Tractor. Slide VI-10. Edison's Improved Phonograph. Slide VI-11. Kodak Camera #1. Slide VI-12. Bell Telephone Equipment. Slide VI-13. First Wright Airplane Engine. Slide VI-14. Ford Assembly Line.

Things to Consider	Teaching Suggestions
9. Prior to World War II basic research was not given any financial support by the U.S. government.	9. Slide VI-15. J. Willard Gibbs Plaque.
10. The scientific tradition of Russia is very similar to that of France; it was started by French scholars during the 18th Century. a. During the Bolshevik Revolution (1918) science was directed toward more practical problems. b. Russian science has always been handicapped by the philosophy of dialectical materialism.	10. Discuss the theoretical and practical aspects of Russian science. Call attention to blind spots in Russian science. Use the Lysenko controversy as an example.

CHAPTER VII. TEACHER'S GUIDE

This chapter introduces radioactivity and some related concepts by considering the success and failure of several pioneers in nuclear science. The discussion of serendipity has been added to impress the student with the fact that scientists frequently encounter unexpected results. It is of value to consider society's response to the discovery of x-rays and radioactivity. These discoveries had a stimulating effect because they contradicted established beliefs and led to new hypotheses and experiments. Introduction of social and scientific attitudes at that time should give the student some perspective into the times at the turn of the century.

Things to Consider	Teaching Suggestions
1. Science has been and can continue to be successful but it has neither the capability nor wisdom to solve all problems; sometimes science helps in the solution of one problem but in the process creates new problems.	1. Introduce this idea with the discussion of the work leading to the harnessing of nuclear energy.
2. At the turn of the century society in Europe and the U.S. was moving at a leisurely and peaceful pace.	2. Slide VII-1. Wright Brothers' Glider.
a. Scientists were content with their accomplishments and thought that all scientific knowledge was known.	
b. The Dalton Atom was considered to be the ultimate particle.	b. Slide VII-2. Dalton's Atom.

Things to Consider	Teaching Suggestions
3. Unexpected but fortunate discoveries often play an important part in scientific investigations.	3. Briefly discuss serendipity; use it to lead into the work of Roentgen and other scientists.
a. Serendipity (the gift of finding valuable things not sought after) has been of importance in nuclear science.	a. Slide VII-3. Crooke's Tube.
b. Roentgen's discovery of x-rays caused a revolution in medical treatment, much concern and anxiety among laymen of the world, and led to further scientific investigations.	b. Slide VII-4. X-ray of Mrs. Roentgen's Hand. Slide VII-5. Life Magazine Cartoon. Slide VII-6. Early Roentgen X-ray Apparatus. Slide VII-7. X-ray of Hand. Slide VII-8. X-raying Luggage.
c. Becquerel discovered radioactivity while investigating the nature of x-rays.	c. Slide VII-9. Becquerel's Discovery.
4. Radioactive decay exhibited by many isotopes is independent of external influence.	4. Integrate this idea with Becquerel's search for an answer to his discovery.
5. Marie Curie found that only minerals with the elements uranium and thorium exhibited radioactivity.	5. Slide VII-10. The Curies. Slide VII-11. Uranium Ore.
6. The discovery of radium and polonium uncovered a greater mystery than x-rays; scientists renewed their speculation about the ultimate particle of matter; radioactivity became popular as an elixir of life.	6. Slide VII-12. Polonium. Slide VII-13. Radium. Slide VII-14. Radioactive Water. Slide VII-15. Quackery.

Things to Consider	Teaching Suggestions
7. Rutherford's experimentation proved that radiation from radium consisted of alpha, beta, and gamma rays; he found that the penetrating power of the radiation was gamma > beta > alpha particles.	7. Slide VII-16. Rutherford's Portrait. Slide VII-17. Electric Properties of Radiation.
8. Some alpha particles deflected by the bombarded gold foil led to the formulation of the solar system model of the atom; Rutherford proposed that each atom had a positively charged nucleus surrounded by electrons.	8. Slide VII-18. Rutherford's Scattering Experiment. Slide VII-19. Rutherford-Bohr Atom.
9. World War I suspended the investigation of the atom; scientists were occupied with activities related to the war; the end of World War I led to renewed study of the atom and to the discovery of artificial transmutation.	9. Discuss the activities of Rutherford (submarine warfare research), Curie (ambulance driver), Chadwick (prisoner of war).
10. Nuclear changes can be produced by penetrating the nucleus of an atom with particles or radiation. a. When a charged particle penetrates the nucleus of an atom the result is the formulation of a different element. b. Artificial transmutation (a synthetic nuclear change) laid to rest the concept of the "indestructible atom."	10. Slide VII-20. Artificial Transmutation. Slide VII-21. Transmutation Mechanism. Slide VII-22. Nuclear Reactions.

Things to Consider	Teaching Suggestions
11. The mass spectrograph (an atom weighing machine) revealed that chemical elements were mixtures of atoms that differed in weight but had the same chemical properties; the term "isotope" was invented to classify atoms of an element which differ in mass.	11. Slide VII-23. Mass Spectrograph. Introduce the discovery of the neutron by discussing the finding and separation of isotopes.
12. The neutron, discovered by Chadwick, caused renewed vigor in nuclear science research and answered questions about the excess mass in the nucleus.	12. Discuss the significance of the discovery of the neutron to later research and discoveries, such as nuclear fission.
13. The identity of an element is determined by the number of protons in the nucleus and the mass of an atom is determined by the number of protons and neutrons in the nucleus. a. The atomic number gives the number of protons. b. The atomic mass number gives the number of neutrons and protons.	13. Briefly review the concepts of atomic number and atomic mass number. Later discussion will be more understandable if the students have some understanding for this concept.
14. $E = mc^2$, matter and energy are equivalent.	14. Briefly discuss this theory of Einstein. DO NOT try to work calculations; merely introduce the idea of the equivalence of matter and energy.

CHAPTER VIII. TEACHER'S GUIDE

The purpose of this chapter is to describe how divergent events came together and resulted in U.S. scientists lobbying to gain financial support for atomic energy research. Emphasis should be placed on Einstein's letter, political instability in Europe, and the unexpected discovery of nuclear fission. Chapter VIII is an introduction to the events that follow in Chapters IX and X; these chapters discuss the results of the involvement of nuclear scientists in political and military affairs.

Things to Consider	Teaching Suggestions
1. Before World War II research in new fields of science such as nuclear science had not been recognized by the U.S. government as a significant national resource. a. Basic research was not given governmental support. b. University scientists did not have representation among government officials. c. Prior to 1939, no regular program for U.S. government support of theoretical science existed.	1. Slide VIII-1. Albert Einstein. Discuss this concept using Einstein's letters as a vehicle. This is an important point when compared to the support of science by the U.S. government today.
2. Einstein's letter to the President, which marked a move toward political involvement by U.S. science, represents a time when social, political, military, and scientific factors of society merged.	2. Continue with the discussion. Call attention to the reluctance of the U.S. government and military to support research for something that had not been proven to be workable.

Things to Consider	Teaching Suggestions
3. Political instability and intolerance of some governments has resulted in the migration of scientists to other countries. a. Central Europe witnessed instability during the pre-World War II years. b. The rise of dictators in Europe had an adverse effect on scholars; they were deprived of security and many lost their professional positions.	3. Slide VIII-2. Lenin. Discuss the rise of dictators and how the climate for scholarly pursuits changed.
4. German science began to decline when the Nazi's gained control of Germany; Nazi philosophy opposed many scientific ideals.	4. Slide VIII-3. Mussolini and Hitler.
5. A handful of gifted scientists, mostly refugees of Hitler and Mussolini, were responsible for the primary discoveries that led to the harnessing of atomic energy.	5. Slide VIII-4. Chicago Pile-1 (CP-1) Scientists.
6. The discovery of the neutron led to the discovery of other natural phenomena exhibited by atomic nuclei.	6. Pick up the thread that was started in Chapter VII and continue with the scientific research that eventually led to the discovery of nuclear fission.
7. The Joliet-Curies made the first artificially radioactive isotopes; this work resulted in the production of many useful radioisotopes.	7. Discuss the discovery of the neutron, positron, and artificial radioactivity and how it encouraged further scientific work. This is an excellent opportunity to show how science advances by a series of small steps.

Things to Consider	Teaching Suggestions
8. Enrico Fermi recognized the possible importance of neutrons for causing transmutation.	8. Discuss the experimentation of Fermi's group and how the results baffled scientists for almost five years.
a. Fermi's experimentation led to the discovery of the moderating abilities of certain substances (wood, graphite, paraffin);	
b. Moderators reduce the speed of neutrons and increase their reactibility with certain nuclei.	
c. Fermi was not prepared to explain what he had observed: the fission of uranium nuclei.	c. Slide VIII-5. Hahn and Meitner.
9. Nuclear reactions differ from ordinary chemical reactions; the nucleus undergoes change in a nuclear reaction.	9. Question: How does a nuclear reaction differ from a chemical reaction?
10. Radioisotopes produced during nuclear fission have half-lives that vary over a wide range; half-life is the time necessary for half of a sample of radioactive material to undergo decay.	10. Slide VIII-6. Diagram of Half-Life.
11. In nuclear fission heavy nuclei split into lighter nuclei when bombarded by particles such as neutrons.	11. and 12. Using the following concepts discuss the race toward the answer of the problem uncovered by Fermi's experimentation. Some of the key events are discussed in the movie: "The Day Tomorrow Began."

Things to Consider	Teaching Suggestions
12. The most crucial test of experimental findings is whether or not they can be repeated by other scientists.	
13. Neutrons were found to be released during nuclear fission; this result indicated that a self-sustained nuclear reaction was possible.	13. Go into detail about this concept in the next chapter, but introduce it at this point.
14. The principal goal for developing nuclear energy by the U.S. during World War II was to deter Hitler from using it as a weapon; Fermi and other immigrants concerned about the lack of interest in atomic energy alerted the U.S. about the potential dangers of atomic energy in the hands of the Nazi's.	14. Show the movie: "The Day Tomorrow Began."

CHAPTER IX. TEACHER'S GUIDE

This chapter is primarily concerned with the "Manhattan Project." The point to stress is the contribution of scientists, military men, businessmen, and government officials to this project. Also of extreme importance is the change in attitude among scientists and goverment officials about governmental support of basic research. The U.S. government invested two billion dollars for a project based on the work of a few research scientists.

Things to Consider	Teaching Suggestions
1. The explosion of an atom bomb is an uncontrolled chain reaction which produces thermal (heat) radiation, gamma radiation, and rapidly moving fragments; mass that is apparently lost when a nucleus splits appears as energy.	1. Discuss the first atom bomb test and emphasize the experimental nature of the whole project at this time.
2. The explosion of the first atom bomb proved to scientists, military men, businessmen, and government officials that their faith in a few scientists had been justified. a. People of different occupations cooperated in the "Manhattan Project." b. The main goal of the "Manhattan Project" was to beat Hitler's scientists to an atomic weapon.	2. Slide IX-1. Map of the Trinity Site. Slide IX-2. The Atom Bomb Test. Slide IX-3. The Atom Bomb Test. Slide IX-4. Ground Zero.

Things to Consider	Teaching Suggestions
3. December 6, 1941 was the day that the U.S. started the "Manhattan Project;" this day marked a change in attitude among U.S. scientists and government officials.	3. Call attention to this change in attitude; gone was the hesitation of spending public money on the theories of a few men.
4. The "Manhattan Project" was an integrated scientific and technological endeavor under the direction of the U.S. Army Engineers; the principal facilities for the "Manhattan Project" were at Chicago; Oak Ridge, Tennessee; Hanford, Washington; and Los Alamos, New Mexico.	4. Slide IX-5. Manhattan District Organization. Slide IX-6. Administrators of the Manhattan District. Discuss the recruiting of workers, the establishment of strict secrecy, and the need for an army of workers for the project.
5. Fermi and Szilard showed that purified graphite could be used as a moderator; it was used instead of heavy water.	5. Slide IX-7. Uranium Metal.
a. Uranium 235 and uranium 238 have 92 protons; but U-238 has three more neutrons than U-235.	a. Slide IX-8. Isotopes of Uranium.
b. Uranium 238 is transmuted to plutonium by neutron bombardment followed by beta decay.	b. Slide IX-9. Pile Reactions. Slide IX-10. Plutonium Sample. Slide IX-11. Plutonium Metal.
6. When nuclei of Pu-239 and U-235 are penetrated by neutrons the nucleus splits, neutrons are emitted, and energy is released; the minimum amount of fissionable material necessary to sustain a chain reaction is known as the critical mass	6. Slide IX-12. Nuclear Fission Chain Reaction. Slide IX-13. Moderated Chain Reaction. Discuss the chain reaction idea using gasoline as an analogy for controlled and uncontrolled chain reactions. Introduce the concept of critical mass.

Things to Consider	Teaching Suggestions
7. An atomic pile (atomic reactor) is an assemblage of fissionable material and a moderator; CP-1 (built at Chicago) was a pile of graphite bricks used as a moderator with uranium and uranium oxide pellets for fissionable material.	7. Slide IX-14. First Atomic Pile (CP-1). Slide IX-15. Atomic Pile Layers. Slide IX-16. Wigner Chianti Bottle.
8. A self-sustaining chain reaction (nuclear fission) occurs when the number of neutrons released by nuclei during fission equals or exceeds the number of neutrons absorbed.	8. Emphasize the need for the neutrons released to be equal to or greater than the number of neutrons absorbed by nuclei. Use a simple example with a small number of atoms.
9. Hanford, Washington facilities consisted of several atomic piles and a chemical processing plant for producing Pu-239.	9. Describe the immensity of the "Manhattan Project" by presenting the various facilities and their contributions to the project.
10. Oak Ridge facilities consisted of equipment for medical research and the separation of U-235 from U-238.	10. Slide IX-17. Mass Spectrograph.
a. Electromagnetic separation is based upon the principle that heavier objects have greater inertia. Light objects are deflected more in a magnetic field than heavy objects.	a. Slide IX-18. Oak Ridge "Racetrack." Slide IX-19. Racetrack Control Room.

Things to Consider	Teaching Suggestions
b. Gaseous diffusion, which is based on the principle that light gas can pass through a membrane more readily than a heavier gas, was used to separate U-235 from U-238.	b. Slide IX-20. K-25 Gaseous Diffusion Plant. Slide IX-21. Gaseous Diffusion.
11. The Los Alamos laboratories were responsible for the construction of the atom bomb mechanism; the mechanisms developed brought together two sub-critical masses to form a critical mass.	11.. Discuss the teamwork that took place at Los Alamos. Also call attention to the security at this camp.
a. U-235, which has a critical mass of 35 pounds, used a gun-type mechanism.	
b. Pu-239, which has a critical mass of 16 pounds, used an implosion mechanism.	b. Slide IX-22. The Gadget.

CHAPTER X. TEACHER'S GUIDE

The purpose of this chapter is to consider: 1) the cooperation between U.S. scientists and military men (Alsos Mission); 2) the overall decline of German science as revealed in their atom bomb research; and 3) the soul searching and decision-making activities of U.S. scientists in regard to the use of atomic weapons. This chapter affords an excellent opportunity to discuss the effect of conditions on the decisions of man.

Things to Consider	Teaching Suggestions
1. Nuclear scientists in the U.S. were racing against German science. a. The principal goal for developing the atom bomb was as a deterrent against Hitler. b. Everyone considered German science to be superior to U.S. science.	1. This is an excellent opportunity to reemphasize the decline of German science during Hitler's time and how secrecy led scientists to overestimate the progress of German science.
2. Secrecy about atomic energy during World War II caused U.S. scientists to believe that they were behind the German scientists; findings of research scientists should be made available to other research scientists.	2. Continue the discussion about secrecy. Question: What do you think would have happened if the atom bomb project had not been kept a secret?
3. The "Alsos Mission," consisting of scientists and military men, was the first scientific and military intelligence mission in U.S. history.	3. Discuss the nature of the "Alsos Mission" and its contribution to the atom bomb race.

Things to Consider	Teaching Suggestions
a. The mission found that the U.S. was competing against a German atom bomb myth.	a. Slide X-1. Toothpaste Ad.
b. The Germans tried to develop a chain reaction but were not successful.	b. Slide X-2. Leipzig Pile. Slide X-3. Critical Pile at the Virus House. Slide X-4. Haigerloch Uranium Pile.
c. The Germans used heavy water because they thought that graphite was not suitable for a moderator.	c. Slide X-5. Dismantling the Haigerloch Pile.
4. Several reasons were responsible for the German failure. a. German scientists seemed to lack vision. b. Key administrative positions were held by incompetent scientists. c. German science was handicapped by a lack of prestige.	4. and 5. Discuss the decline of sympathy for German science among the Nazi's and decline of German science. The failure of German science to develop an atom bomb is an excellent example of this decline.
5. A sympathetic government policy toward science is important in developing and maintaining scientific activities.	
6. Active participation of scientists in U.S. politics is primarily due to the development of atomic energy; decisions in matters of atomic energy are intimately related to science and technology.	6. Slide X-6. Officials of the Manhattan Project. Slide X-7. Manhattan Project (S-1 Committee).

Things to Consider	Teaching Suggestions
7. Scientists began to realize the political, military, and moral implications of atomic energy.	7. Discuss the predictions and recommendations made by nuclear scientists.
a. The Bohr Memorandum discussed several implications of atomic energy.	a. Atomic energy would revolutionize industry and transportation.
b. The Szilard letter advocated international control.	b. War research would become more intense.
c. The Franck Report suggested that the U.S. either keep the atom bomb a secret or exhibit its power through a non-military demonstration.	c. Atomic weapons would become a perpetual menace.
	d. Openness about research findings and international control are necessary.
8. The Interim Committee advised the President to use the atom bomb on military-industrial centers in Japan; the events and conditions determine the decisions and actions of men.	8. Discuss the effects of conditions on the decisions and actions of men. Try to get the students to consider what they would have decided under the conditions of World War II.
9. The "Little Boy," a U-235 gun-type atomic device, was dropped on Hiroshima.	9. Slide X-8. "Little Boy." Discuss the critical mass concept.
10. The "Fat Man," a Pu-239 implosion device, was dropped in Nagasaki.	10. Slide X-9. "Fat Man."
11. The Japanese reluctantly surrendered after the second atom bomb attack.	11. Call attention to the desire of some Japanese military leaders to continue the war.

Things to Consider	Teaching Suggestions
12. The U.S. developed the bomb to deter the Nazi's, but was the first country to use it; scientists, military men, businessmen, and politicians were responsible for the use of this weapon.	12. Call attention to the fact that the U.S. is the only country that has used a nuclear weapon against people.
13. Most people agree that the utilization of atomic energy must be administered by rational and emotionally stable people.	13. Lead into the next chapter using this idea as the starting point.

CHAPTER XI. TEACHER'S GUIDE

This chapter emphasizes the change in attitude among scientists; they became involved in politics in order to prevent the control of the utilization of atomic energy to be released to the military or private industry. The chapter briefly considers the failure of international control and the split of scientists into three schools of thought. It is of interest to show that all scientists do not think alike. The second part of this chapter considers the peaceful uses of atomic energy, while Chapter XII will consider several risks associated with the use of atomic energy.

Things to Consider	Teaching Suggestions
1. Since the start of the "Manhattan Project" the influence of scientists on government has increased.	1. Slide XI-1. Japanese Surrender. Call attention to the fact that problems associated with atomic energy were just beginning.
2. Scientists found themselves in a very unusual position; they were public heroes and were looked upon as a major source of national power.	2. Emphasize the change in the image of scientists in the U.S. Question: Were the scientists able to cope with their new image?
3. Scientists divided their opinion on the role of science in the service of government. a. One group advocated withdrawal of scientists from public service. b. Another group advocated expanded participation in public service.	3. Discuss the division of scientists behind the leadership of Norbert Weiner and Edward Teller.

Things to Consider	Teaching Suggestions
4. The processes for the production of fissionable materials for nuclear explosives and nuclear fuels are identical; control of military uses of nuclear energy requires the control of all aspects of the production and utilization of fissionable materials.	4. Slide XI-2. Steps in the Supply of Atomic Fuel. Slide XI-3. Plutonium Production Flow Diagram. Emphasize this point; it is the key to the need for the control of atomic energy.
5. The control of atomic energy resolves into issues: a. Domestic. b. International.	5. Establish these two issues. Then discuss the attempts to solve them.
6. The domestic issue was solved with the establishment of the Atomic Energy Commission (AEC). a. The AEC controls all aspects of atomic energy utilization in the U.S. b. The AEC is a controlling agency free of the profit motive. c. The AEC has established many national laboratories for nuclear energy research.	6. Emphasize the following. The AEC is: a government agency; a non-military agency; and a profit-free controlling agency. Dicuss the political activities of scientists to win passage of the McMahon Bill in the U.S. Senate.
7. The international issue of control has not been solved, but some steps have been taken toward international regulation; the Baruch Plan, which proposed international control of atomic energy, failed because of international politics.	7. Discuss the Baruch Plan and its failure. Emphasize the influence this failure had on the increased involvement of scientists in national security policies. Discuss the split of scientists into the three schools of thought: 1) control; 2) finite containment; and 3) infinite containment.

Things to Consider	Teaching Suggestions
8. The perfection of thermonuclear devices resulted in the "Atoms for Peace" proposal, which offered assistance for peaceful uses of atomic energy.	8. Call attention to the escalation in testing and the political move made by the U.S. to establish international regulation of atomic energy.
a. In a nuclear fusion reaction nuclei of lighter elements are combined to form a nucleus of a heavier element.	a. Slide XI-4. Thermonuclear Triple Threat. Slide XI-5. Hydrogen Bomb Test in the Pacific.
b. The "Atoms for Peace" program gave impetus to industrial applications and controlled assistance to developing nations.	b. Discuss the controlled assistance idea. Call attention to the potential peaceful uses of nuclear explosives (Project Plowshare).
c. The International Atomic Energy Agency (IAEA) administers the "Atoms for Peace" program.	c. Slide XI-6. Dam Building. Slide XI-7. A New Panama Canal. Slide XI-8. Sites for a New Panama Canal.
9. The first U.N. Geneva Conference for "Atoms for Peace" was an historic event; it was the first time that diplomats sat together with scientists from various countries.	9. Call attention to the change in the image of scientists from a national to an international force.
10. Atomic Energy has many benefits for society; numerous nuclear reactors have been put into operation in many parts of the world.	10. Slide XI-9. Atomic Reactor Design. Slide XI-10. Cross Section of a Reactor. Slide XI-11. Energy Patterns Today. Slide XI-12. Breakdown of Costs.

Things to Consider	Teaching Suggestions
a. Nuclear chain reactions can be very rapid or it can be slowed down so that the production of heat energy can be controlled.	a. Compare the burning of gasoline in an internal combustion engine and a gasoline explosion to controlled and uncontrolled chain reactions.
b. A nuclear reactor(or pile) is an assemblage of fissionalbe material and a moderator. c. Useful control rods absorb neutrons and control the rate of fission. d. Heat released during nuclear fission or radioactive decay can be converted into power. e. One unique characteristic of a nuclear reactor is its geographic independence. f. Atomic energy can make it possible to build cities in regions where power sources are not available.	b. to f. Include these points in the discussion of benefits of nuclear power reactors. Some have been discussed earlier with the topic of nuclear power reactors (Chapter I).
11. Radioactive atoms (radioisotopes) produce valuable energy in the form of heat and other radiations which can be adopted for a variety of scientific, medical, agricultural and industrial uses. Radioisotopes decay at a rate that is independent of external influences.	11. Slide XI-13. Basic Principles of Radioisotope Utilization. Movie: "Radioisotopes: Safe Servants of Industry."
12. Radiochemical techniques are used to study soils, plants, microbes, insects, and farm animals	12. Slide XI-14. Food Irradiation Plant. Slide XI-15. Irradiation of Food.

Things to Consider	Teaching Suggestions
13. Radioisotopes have many industrial uses such as gaging and nondestructive inspection (radiography).	13. Slide XI-16 and 17. Radioisotopes for Gaging. Slide XI-18. Detecting Leaks. Slide XI-19. Leveling Gage. Slide XI-20. Radiography. Slide XI-21. Test for Washing Efficiency.
14. Radioisotopes are powerful agents for diagnosing and treating diseases.	14. Slide XI-22. Whole Body Scanning. Discuss the key factor in the use of tracers: their chemical properties.
a. Arsenic 74 is used to detect brain tumors.	
b. Iodine is a versatile tracer and therapeutic element (I-131 and I-132).	b. Slide XI-23. Iodine 31.
c. Sodium 24 is used to evaluate the circulation of blood.	c. Slide XI-24. Sodium 24.
d. Phosphorus 32 is used in the treatment of polycythemia vera.	d. Slide XI-25. Phosphorus 32.
e. Boron 10 is used in the treatment of brain tumors, but boron compounds are poisonous.	e. Slide XI-26. Neutron Capture Therapy.
f. Cobalt 60 and Cesium 137 emit high energy x-rays which are used for the treatment of deep-seated cancers.	f. Slide XI-27. Cesium Sample. Slide XI-28. Rotational Teletherapy.

CHAPTER XII. TEACHER'S GUIDE

This chapter considers some of the persistent risks and the future of atomic energy. In addition, a summary of the history of science and the future of science is discussed. Some questions presented in the chapter cannot be answered or do not have any one correct answer. It is important for the student to realize that many questions do not have simple answers.

Things to Consider	Teaching Suggestions
1. If the problem of atomic weapons control is solved the problem of radiation will still persist.	1. Slide XII-1. Nuclear Treaty of 1963.
2. Many years will be needed to perfect nuclear technology so that it will become more efficient and less costly.	2. Slide XII-2. Risks of Nuclear Energy.
3. Nuclear power plants cost more to build than regular power plants; they must include many safety devices. a. The protection of the worker and general public are crucial to the development of applications of atomic energy. b. Radioactivity cannot be neutralized and destroyed by any known process. c. The world is faced with a problem of the safe disposal of large quantities of radioactive waste materials.	3. Discuss the treatment of the strongly and weakly radioactive waste components of a nuclear reactor. Slide XII-3. Table of Radiation Dosage. Slide XII-4. High Intensity Radioactivity Storage. Slide XII-5. Underground Mine Storage. Slide XII-6. Low Intensity Radioactivity Treatment.

Things to Consider	Teaching Suggestions
4. Nuclear radiation is a hazard to all living organisms. a. The danger of radioactivity is lethal radiation. b. Radiation cannot be detected by any of the natural senses. c. Ionizing radiation can cause mutations in all living organisms other than those in nature; genetic defects cannot be corrected at present. d. The damage caused to genes in reproductive cells is cumulative and irreversible and leads to mutations.	4. Slide XII-7. Radiation Absorption. Slide XII-8. Chromosome Damage. Slide XII-9. Effects of Radiation. Slide XII-10. Innocence. Slide XII-11. Bone Cross-Section. Slide XII-12. Bone Cross-Section (self-photograph). Discuss the hazards of radiation and follow with a discussion of the safety regulations of the AEC.
5. Fear of radiation is the biggest obstacle to the acceptance of atomic energy by people. a. Safety measures for the use of atomic energy are well-planned and strictly enforced. b. Health protection officers supervise all operations of workers in reactor areas. c. The Atomic Energy Commission and the International Radiological Commission have drawn up strict security rules for the building and operation of facilities using radioactive materials.	5. Slide XII-13. Radiation Detection Machine. Slide XII-14. Hot Laboratory Experimentation. This whole area of radiation security is under careful study. No one knows what the answers to this problem will be. Encourage the students to suggest possible answers. Question: How can we obtain the benefits of atomic energy without accepting the risks? Movie: "The International Atom."

Things to Consider	Teaching Suggestions
d. A large amount of research is being directed toward radioisotopes in man's food chain.	
6. The atom has been viewed differently by different societies. a. The atom holds great promise for the well-being of civilization. b. Possession of nuclear fuels is a measure of the strength and wealth of a nation.	6. Slide XII-15. Models of Matter. Summarize the history of the atom and its significance today.
7. Countries with a limited development of natural resources could benefit from a well-established scientific community. a. Government supported science is effective in meeting the internal needs of a country. b. Science is important in establishing the international political position of a country.	7. Slide XII-16. Span of Time. Call attention to the great technical gap between communities of the world; the slide shows the gap within India.
8. The scientists has been viewed differently by different societies.	8. Review the cycles of science from early man to the present.
9. The diminishing gap between scientific discovery and technological application necessitates a higher degree of social responsibility on the part of the scientist.	9. Discuss the need for social responsibility of all citizens. Question: Why should research findings be made available to all other scientists?

Things to Consider	Teaching Suggestions
10. Social techniques are needed to insure that decisions made by politicians, with the advice of a few scientific experts, concerning scientific research will truly reflect the needs of society.	10. Question: How can we promote scientific research and at the same time insure that this research is in our best interest?

MOTION PICTURE DESCRIPTIONS

The following films were used in the unit. They are available without charge from the Atomic Energy Commission Technical Information Division, Oak Ridge, Tennessee and field film libraries.

Chapter I. NUCLEAR ENERGY GOES RURAL (1963). 14½ minutes, color. Produced by USAEC's Chicago Operations Office.

This film presents the background, planning, and construction of the Elk River Reactor for Minnesota's Rural Cooperative Power Association. After the rural background and setting are established, the planning of the reactor is shown. Animation is used to explain the principle of the boiling water reactor with conventional superheated steam. A comparison is made with the hot air heating system used in the home, and the reactor's control rods are compared with a thermostat. The reactor control room is shown. A "Scram" is explained. Fuel operations are also explained, as well as the air monitoring system.

Chapter VIII - IX. THE DAY TOMORROW BEGAN (1967). 30¼ minutes, color. Produced by AEC's Argonne National Laboratory.

This historical film tells the story of the building and testing of CP-1 (Chicago Pile-1), the first atomic pile, and the work of the brilliant scientific team, led by Dr. Enrico Fermi, which ushered in the Atomic Age behind a cloak of wartime security under the stands of Stagg Field, Chicago, December 2, 1942.

By interview, historical footage, paintings, etc., the film takes us on a step-by-step re-enactment of the famous event--beginning with the arrival of the first refugee scientists in 1939, to the dramatic hours in late 1942 when control rods were pulled out of CP-1 an inch at a time, to achieve the first sustained chain reaction.

THE DAY TOMORROW BEGAN (continued)

Interviews are conducted with some of the members of the team and people closely associated with them--John Wheeler, Mrs. Laura Fermi, Walter Zinn, Herbert Anderson, Norman Hilberry, and Mrs. Leona Libby.

Against the background of a world plunged into World War II, the Third Reich hard on its way to developing an atomic bomb, uranium metal almost a laboratory curiosity, and with seemingly unsurmountable problems to be solved--the story of this brilliant scientific tour-de-force brings into focus the work of such people as Dr. Fermi, Leo Szilard, James Conant, Vannevar Bush, Arthur Compton, Ernest Lawrence and others.

Chapter XI. RADIOISOTOPES: SAFE SERVANTS OF INDUSTRY (1963). 28 minutes, color. Produced by Molesworth Associates and Orleans Film Productions for the USAEC's Division of Isotope Development.

With emphasis on safety, this film surveys the widespread uses of radioisotopes in industry. Animated explanations of the principles involved in radioisotope gauging instruments, tracing and radiography are given. Applications of these principles are shown in various processes in the food industry, automotive research, road construction, heavy industry, oil refining and shipping, and system troubleshooting.

Chapter XII. THE INTERNATIONAL ATOM (1961). 27 minutes, color. Produced by the United Nations Office of Public Information and the International Atomic Energy Agency, for the UN Visual Information Board.

This film, which summarizes and explains the peaceful uses of atomic energy, was produced with the assistance of the government atomic energy establishments and private industry of the following countries: the United States, Canada, West Germany, France, India, Japan, Mexico, Netherlands, Norway, Switzerland, the United Kingdom, and the USSR. The film defines fission and chain reaction, introduces the idea of heat generation by a nuclear reactor, mentions the use of nuclear power for ship propulsion, stresses the need for international cooperation in the atomic field, explains what radioisotopes are and how they are packed and shipped, explains how radioisotopes and radiation are used in agriculture (rice fields, fertilizer studies, development of stronger strains of weather- and disease-resistant food crops, eradication of the screwworm fly, etc.).

NARRATION FOR THE SLIDES USED IN THE UNIT

SLIDES - CHAPTER I

I-1. Types of Nuclear Power Reactors. United States Atomic Energy Commission. 1964. Nuclear Reactors. Oak Ridge, Tennessee. Division of Technical Information. p. 39.

There is nothing magical about a nuclear power plant. The diagrams shown could be used to explain the scheme of a conventional power plant. All that is necessary is to replace the reactor with a boiler that burns fossil fuel. A conventional power plant and a nuclear power plant produce heat that converts water into steam. One produces heat by combustion and the other by nuclear fission.

I-2. Energy Patterns Today. United States Atomic Energy Commission. 1968. Sources of Nuclear Fuels. Oak Ridge, Tennessee. Division of Technical Information. p. 5.

As the diagram shows atomic energy represents just a small amount of the total energy source in the United States at present. Most other countries use less atomic fuel than the United States. Why are we using such a small percentage of nuclear fuel for power? When will we use more atomic energy? What problems will we have to solve? These are questions that we will consider during this unit.

I-3. Comparison of Uranium to Coal. Peaceful atom sparks a war. Life. 67:11:27.

It is easy to see why uranium would be an excellent fuel to be used for the production of electricity. The uranium being held has the same energy value as the pile of coal in the background. In addition, air pollution due to smoke is eliminated.

I-4. Energy Comparison. United States Atomic Energy Commission. 1965. Plutonium. Oak Ridge, Tennessee, Division of Technical Information. p. 5.

This slide is for those who like to think in terms of coal cars or are curious about the energy value of plutonium.

I-5. Nuclear Power Plants in the United States. United States Atomic Energy Commission. March 31, 1969.

This slide shows the location of nuclear power plants that are operating and being planned at the present time. Note that most of these are being built in areas of high population and industry. These are areas of high demand for electricity. This demand is continually increasing. However, regions such as the Rocky Mountains area having only a few reactors will eventually have more. Reactors will enable cities to flourish in these sparsely populated areas.

I-6. Time Chart of Main Periods of Science. Taylor, F. Sherwood. 1949. A Short History of Science and Scientific Thought. New York: W. W. Norton Co., Inc. Opposite Table of Contents.

The development of atomic energy is the result of many years of work. It did not come into existence overnight. In fact, it could be said that atomic energy is the product of centuries of work. In this unit we are going to consider the development of atomic energy and its social implications, but to give you a better perspective we will go into the past and look at the scientist and his relationship to society. We will begin with the Egyptians and Mesopotamians (called Assyrians in this chart), then we will consider Greek science, and finally the contributions of Arabian and early Christian science. We will look at some of the motives and men that were in part responsible for the revival of science during the 16th and 17th Centuries. Finally, we will look at the change in the scientists from the amateur to the professional and how science has gone from the practice of individuals to research teams supported by national governments.

I-7. Chart of Historical Cycles. Mees, C. E. K. 1946. The Path of Science. New York: Wiley and Sons. p. 36.

Many of you probably think that science is just a modern phenomena. But science is a social activity that began with man. It has gone through a series of cycles during which it has been more popular. The emphasis of science has changed from time to time; at times it has been very theoretical and at other times applied science has been emphasized. It is of interest to note that other activities are cyclical. For example, the line that tends to run vertically down the slide traces the rise of sculpture during various periods of history. If we were to study the history of other art forms we would find that their rise and fall would coincide closely to the rise and fall of science and civilizations. When does astrology become most popular in a civilization? (Keep this question in mind as you read this unit.)

SLIDES - CHAPTER II

II-1. Cave Drawing - Hunting Season Worship. Barnet, Lincoln. 1962. The Epic of Man. New York: Golden Press. p. 29.

This artist's conception of early man depicts what may have taken place in the caves in which drawings and carvings have been found. We do not know for sure the significance of these drawings but we do believe it was related in some way to their worship. These drawings indicate that these men were careful observers of their surroundings; one aspect of the activity of science. These men must have known something about pigments and the utilization of fire (such as oil lamps). This is an initiation with new members, noise makers, and a priest (Shaman).

II-2. Early Farming Tool. Barnet, Lincoln. 1962. The Epic of Man. New York: Golden Press. p. 38.

At some point in his history man discovered farming and the domestication of plants and animals. He settled in communities rather than remain a nomad. This slide shows a sickle made from flint. Why did they choose to use flint? This tool shows that pre-historic man must have made tools by trial and error.

II-3. Pottery Tray. Barnet, Lincoln. 1962. The Epic of Man. New York: Golden Press. p. 38.

This bowl was used for separating the husks of grain from the grain. This represents another accomplishment for early man--again by trial and error. They stored their grain in pottery containers. As man established larger farming communities he had to find better land to support the growing of crops. As a consequence, when man became what we call civilized he formed communities in areas where there was an ample supply of fertile land.

II-4. Map of the Fertile Crescent. Neill, Thomas. 1968. Story of Mankind. New York: Holt,Rinehart and Winston. p. 27.

There were three civilizations that started about 4000 B.C. This map shows the two that we will consider. The one area known as Iraq was known as Mesopotamia in the past. A civilization thrived between the Tigris and Euphrates Rivers. The rivers gave the people much fertile land. The Mesopotamians built canals to drain swamp areas and irrigation ditches to water other areas. The other center was along the Nile. I have another slide to show this area in more detail, but I want you to see how close they were to each other.

II-5. Map of the Nile River Valley. Neill, Thomas. 1968. Story of Mankind. New York: Holt, Rinehart and Winston. p. 38.

The Egyptians developed their culture along the Nile River. They did not know the source of the Nile but that it flooded once a year and it furnished much fertile land for agriculture. It is amazing how the character of the Nile and the Tigris-Euphrates Rivers influenced the thinking of these people. They made interpretations about their surroundings which included the bodies of water.

II-6. Early Mesopotamian Pottery. Piggott, Stuart. 1961. The Dawn of Civilization. New York: McGraw-Hill Book Company. p. 49.

This slide shows pottery that was made and decorated by craftsmen in early civilizations. This pottery, which was found in fragments at a site in Mesopotamia, had been made as early as 5500 B.C.

II-7. "Scarlet Ware" Vase. Piggott, Stuart. 1961. The Dawn of Civilization. New York: McGraw-Hill Book Company. p. 69.

This vase was reconstructed from fragments found in an archaeological site in Mesopotamia. It has been found to have been made about 3100 B.C.

II-8. *Early Mesopotamian Chariot*. Barnet, Lincoln. 1962. *The Epic of Man*. New York: Golden Press. p. 40.

This is an artist's conception of life in early Mesopotamia (probably about 3000 B.C.). They had carriages of this type drawn by horses. I am showing this slide to call attention to the wheels of this type that have been found at archaeological sites. The wheels were made of pieces of wood joined together rather than cutting across tree trunks. The question is why?

II-9. *The Universe as Conceived by the Chaldeans* (Mesopotamians). Masperro, Gaston. 1922. *The Dawn of Civilization*. New York: Macmillan Company. p. 543.

The universe was conceived differently by the Egyptians and Mesopotamians. They were probably influenced by their environment. The Mesopotamians considered the heavens to be a vault and the river running along the mountains to the edge of the earth. They believed that the mountains supported the heavens.

II-10. *The Universe as Conceived by the Egyptians*. Masperro, Gaston. 1922. *The Dawn of Civilization*. New York: Macmillan Company. p. 17.

Contrast this slide with the last slide. The Egyptians believed the universe to be a box with the earth at the bottom and the heavens on top. Heavenly bodies were believed to suspend from the ceiling. The source of the Nile was believed to be a universal river that ran across the earth. In the upper left hand corner is a boat that is sailing on the universal river. The Egyptians believed that the sungod traveled on this boat once daily, thus night and day. The hieroglyphic terms for face - south, back of head - north, left - east, and right - west were the same. Thus, the Egyptians probably invented the four directional terms.

II-11. *Cuneform Writing*. Goudsmit, S. A. and R. Claiborne. 1966. *Time*. New York: Time, Inc. p. 66.

This slide shows a Babylonian calendar tablet made about 103-101 B.C. It is recording the intervals from new moon to new moon during a 25-month period. This is the predictive of Mesopotamia. The writing (predictive science) was the writing language of the Mesopotamians. Most people could not understand the writing so management was placed in the hands of the literate--a select few.

II-12. Mesopotamian Scribes. Carpenter, Phys and others. 1961. Everyday Life in Ancient Times. Washington, D.C.: National Geographic Society. p. 31.

This is an artist's conception of priestly scribes writing on clay. They used a sharp object (stylus) to flick pieces of clay out of the tablet. The man with the beard and the man next to him are using special wheels to make special inscriptions and designs in clay. These wheels were used as monogramed wax seals and have been used in recent times. Note how the scribe is holding the stylus.

II-13. Egyptian Hieroglyphics. Breasted, James. 1930. The Edwin Smith Surgical Papyrus. Chicago: University of Chicago Press. p. 244.

The Egyptians used this form of writing to pass information to later generations. This slide shows the medical prescription for treating a broken nose. In order to read it you must read from right to left (plus understand hieroglyphics).

II-14. Egyptian Scribes. Carpenter, Phys and others. 1961. Everyday Life in Ancient Times. Washington, D.C.: National Georgraphic Society. p. 103.

The Egyptians knew how to make paper from papyrus. This is an administrative staff circa 2500 B.C. Once a man became a scribe he automatically became a member of the official educated class. He was exempt from all menial labor.

II-15. Gold Sculpture. Piggott, Stuart. 1961. The Dawn of Civilization. New York: McGraw-Hill Book Co. p. 80.

The Mesopotamian and Egyptian scribes controlled most daily activities. But these culture also had excellent craftsmen who made objects from metals, stone, and clay. This goat and tree are made from gold and silver; the goat has a coat of lapis lazuli. This statue is believed to be an idol for worship, perhaps an idol of fertility.

II-16. Mesopotamian Warrior Helmet. Piggott, Stuart. 1961. The Dawn of Civilization. New York: McGraw-Hill Book Company. p. 80.

This is a helmet made of solid gold and was worn by an ancient Mesopotamian prince (Prince Meskalamshar - c. 2500 B.C.). The markings on the side indicate the royal hair style of the time. This helmet was found on the head of its owner. The skull was so well preserved that it was possible to determine that he was left-handed.

II-17. Copper Cooking Ware. Piggott, Stuart. 1961. The Dawn of Civilization. New York: McGraw-Hill Book Company. p. 122.

This slide shows copper cookware made by craftsmen. All these objects were hammered from copper. This group of vessels was made about 2500 B.C.

II-18. Egyptian Glass. Smith, R. W. 1964. History revealed in ancient glass. National Geographic. 126:3:363.

This craft dates back to about 2000 B.C. The figure is made from strips of glass laid side by side and fused together.

II-19. Egyptian Medicine. Carpenter, Phys and others. 1961. Everyday Life in Ancient Times. Washington, D.C.: National Geographic Society. p. 138.

This Egyptian relief is a tribute to medicine, in particular I-em-hotep (God of Medicine). This relief dates back to about 2800 B.C. and indicates that the Egyptians had an established school of medicine. It was a practical type of medicine that attempted to cure illness by the use of various types of herbs. Other murals show physicians referring to the papyrus scrolls for remedies.

II-20. Mesopotamian Medicine. Carpenter, Phys and others. 1961. Everyday Life in Ancient Times. Washington, D.C.: National Geographic Society. p. 50.

The Mesopotamians were more superstitious and treated their patients with magical incantations. This slide shows a patient lying on a table with a cloth over his face and physicians praying over him. At the table is a physician consulting a sacrificial liver (the Mesopotamian "Journal of Medicine"); it is a clay replica of a sheep's liver. They believed in diagnosing and treating illnesses by use of these sacrificial livers. The priest wears a fish-like hood symbolic of their belief in a water god.

II-21. Copper Replica of a Sacrificial Liver. Nourse, Alan.
1964. The Body. New York: Time, Inc. p. 23.

This is a copper replica of a sacrificial liver, found in the ruins of a Roman village. This is a more up-to-date reference tool for physicians, a later edition of the clay liver. The liver was divided into parts and each part represented a particular omen or indication. What the Mesopotamians would do would be to take a lamb, sacrifice it, and cut it open to observe the position of the sacrificial liver. From their observations they decided on a diagnoses and treatment.

II-22. Days of the Week. Lodge, O. J. 1960. Pioneers of Science. New York: Dover Publications. p. 5.

The Mesopotamian scribe was responsible for predicting the time of planting and harvesting. They also set the dates for feasts for the various gods. This required them to observe various heavenly bodies. They found that all heavenly bodies appeared to be in a fixed position except for seven--the sun, moon and five planets. They believed these moving heavenly bodies controlled all activities on earth. They believed that every hour of the day was controlled by these heavenly bodies. For example if we assume as they did that the first hour of the day was controlled by the sun, then the second hour was controlled by the planet Venus, the third Mercury, the fourth the moon, the fifth Saturn, the sixth Jupiter and the seventh Mars, the eighth hour is under the control of the sun and so on. They continued counting until they had 24 hours. The start of the next day was then under the control of the heavenly body that was 25th and the counting begins again.

II-23. Egyptian Merkhet. Hoyle, Fred. 1962. Astronomy. Garden City, New York: Doubleday and Company. p. 36.

The Egyptians did not have a well developed astronomy. This slide shows the instrument (merkhet) used by the Egyptians for sighting stars. One person held the plumb line while another person looked through the opening in the staff. By sighting stars from different points they could determine direction. This was an early method for tracing the motion of stars through the sky.

II-24. Egyptian Scribes. Benjamin, David. 1963. Mathematics. New York: Time, Inc. p. 74.

This mural, which is 3000 years old, depicts various activities in the life of ancient Egyptians. The upper diagram shows the surveyor with his rope used for measuring. Note the knots on the rope. These surveyors were scribes who knew how to write and keep track of plots of land. Many Egyptian reliefs and wall murals show individuals recording and supervising daily activities.

II-25. Egyptian Pyramids. Piggott, Stuart. 1961. The Dawn of Civilization. New York: McGraw-Hill Book Co. p. 111.

The Egyptians left an impressive record as architects and engineers. The three pyramids shown in this slide were constructed with such precision that the corners are almost perfect 90-degree angles. The largest pyramid (the distant one) is 250 yards long and 158 yards high (Kheops pyramid).

II-26. Artist's Conception of the Pyramids. Piggott, Stuart. 1961. The Dawn of Civilization. New York: McGraw-Hill Book Company. p. 118.

The artist's conception of the three pyramids are shown in this slide. This was probably what the architecture looked like at the time of completion. Again, this indicates that early civilizations had a fairly well developed scientific activity; it was probably a very practical or applied science (pyramids were made for Kheops, Klephren, Mykerinus--about 2600 B.C.).

SLIDES - CHAPTER III

III-1. Map of Ancient Greece. Neill, Thomas. 1968. Story of Mankind. New York: Holt, Rinehart and Winston. p. 92.

While Egyptian and Mesopotamian science was a type of practical science (i.e., calendar development), the Greeks started what is considered to be theoretical science. They speculated about nature without being concerned with the application of knowledge. The Greek culture is believed to have been derived from the island of Crete but much is not known about this earlier culture. About 600 B.C. the port city of Miletus opposite the island of Samos produced a number of theoretical scientists. The first of these was Thales. The scientists were members of the leisure class and were able to devote much time to speculation about nature.

III-2. Greek Olive Grove. Carpenter, Phys and others. 1961. Everyday Life in Ancient Times. Washington, D.C.: National Geographic Society. p. 211.

This is an artist's conception of a day in the life of the Greeks. Note the people working in the background; they were the slaves owned by the landlord of this grove. The oil obtained from the olives (right foreground) was used for cooking and oil lamps. The two men in the left foreground represent members of the leisure class. They were not concerned with everyday manual tasks but spent much time discussing politics, philosophy, and speculating about nature.

III-3. Greek Opinion Poll. Carpenter, Phys and others. 1961. Everday Life In Ancient Times. Washington, D.C.: National Geographic Society. p. 247.

A question often asked is "Why were the Greeks able to speculate and not other people of this time?" One of the possible answers was greater freedom. This slide represents activity in a Greek market place. The people are casting votes (on clay shards) or as the Greeks would say, ostrakon. If a member of the leisure class disliked another member he called for a vote. If the vote was unfavorable the accused would be banished from the community or at least lose all of his rights for a period of time. You have probably heard the term

III-3. Continued

"ostracize;" it was derived from this Greek word. This is an example of the freedom of spirit which existed at the time of the Ancient Greeks. They had a democracy but only for the leisure class; women, children, and slaves did not enjoy this status.

III-4. Athenian School. Carpenter, Phys and others. 1961. Everyday Life in Ancient Times. Washington, D.C.: National Geographic Society. p. 228.

Education was an individual enterprise. This slide shows various activities taking place in the school in Athens. Plato's Academy and Aristotle's Lyceum were probably similar to this school. Wealthy people sent their children to school or hired a tutor. The seated gentleman is probably a school master. It was at schools of this type that early Greek science was taught.

III-5. Greek Architecture. Caprenter, Phys and others. 1961. Everyday Life in Ancient Times. Washington, D.C.: National Geographic Society. p. 238.

This slide shows the construction of one of the Greek buildings. These men were craftsmen whose work was considered slave labor. The scholars would not take part in this type of activity so Greek intellectual activity was primarily theoretical (science included). The Greeks did not perform experiments since experimentation was considered to be manual labor. Note that the craftsmen are not using mortar; they fastened the blocks by using metal (bronze) clamps.

III-6. Plato's Elements. Ihde, Aaron. 1964. The Development of Modern Chemistry. New York: Harper and Row Company. p. 5.

These five figures were the elements according to Plato. He did not believe in atoms, but he did believe in a mathematical unit (the triangle). He considered the four elements of Empedocles to be geometric figures. Each figure could be made of a simple triangle. The elements are air (octahedra); water (eicosahedra); earth (cubes); fire (tetrahedra); and quintessence (dodecahedron). He urged the design of the universe along geometrical lines.

III-7. Aristotle's Four Elements and Four Qualities. Ginger, Ray. 1959. Spectrum. New York: Holt and Company. p. 7.

The atomic theory of Democritus was discouraged by Aristotle who believed that there were four elements and four qualities. He believed that by changing a quality of an element into its opposite he could change the element. He also believed that matter was continuous and could not be broken into atoms. He believed that you could continually subdivide matter. What Aristotle meant was that water has the qualities of wet and cold. If you change the quality of cold to its opposite, hot, Aristotle believed that you would change the element water into air. This was the theory of matter until the 19th Century.

III-8. The Universe as Viewed by the Greeks. Hoyle, Fred. 1962. Astronomy. Garden City, New York: Doubleday and Company. p. 86.

The Greeks believed that the earth was at the center of the universe. They believed that the earth was a sphere and that other heavenly bodies circled the earth on their own separate spheres. The moon was the closest body, then came Mercury and Venus, the sun, the planets Mars, Jupiter and Saturn, and finally the sphere of stars. The people believed in a supernatural being that lived beyond the stars; he was called the "Prime Mover."

III-9. Alexander's Empire. Neill, Thomas. 1968. Story of Mankind. New York: Holt, Rinehart and Winston. p. 114.

Athens was the center of Greek science until Alexander conquered Egypt and established the port city of Alexandria. Many of the Greek scientists went to Alexandria to work at the "Museum." This map shows the extent of Alexander's Empire. On his travels, Alexander took with him scientists and engineers who brought back knowledge from distant parts of the empire. At this time, Greek science became very empirical. The theoretical scientists tended to vanish from the scene.

III-10. Ptolemy's Epicycles. Lodge, O.J. 1960. Pioneers of Science. New York: Dover Publications. p. 22.

As the Alexandrian era of Greek science drew to a close; science became more superstitious. The scientists developed horoscoping and fortune telling. This slide shows one of the last real contributions of Greek science. The loops (epicycles) were invented by Ptolemy to explain irregularities in the motion of the planets as they circled the earth. This theory was a refinement of Aristotle's concept of the universe. This was the dominant theory about the universe until the 17th Century.

III-11. Universe at the Close of Alexandrian Science. Hoyle, Fred. 1962. Astronomy. Garden City, New York: Doubleday and Company. p. 67.

This drawing (made in A.D. 1500) shows the universe viewed from the time of the Ancient Greeks to the time of Galileo. This is a summary of the contributions of the Mesopotamians, Egyptians, and the Greeks. The Greeks were responsible for the earth being the center of the universe. The Mesopotamians were responsible for the Zodiac. The Mesopotamians divided the heavens into twelve parts and the Egyptians added horoscoping.

SLIDES - CHAPTER IV

IV-1. Map of the Roman Empire at its Greatest Extent. Neill, Thomas. 1968. Story of Mankind. New York: Holt, Rinehart and Winston. p. 135.

The Romans conquered much of the Mediterranean region. They were excellent administrators and engineers but were not interested in theoretical science. The Romans were more noted for their works of engineering than for the development of any new ideas in science. The Roman Empire was held together by excellent roads to transport troops and supplies.

IV-2. Roman Arch Bridge in Spain. Carpenter, Phys and others. 1961. Everyday Life in Ancient Times. Washington, D.C.: National Geographic Society. p. 305.

This Roman arch bridge is an excellent example of Roman engineering. The whole structure, made of granite blocks, is 200 feet in height. It was built at Alcantara, Spain (about A.D. 100). Note the tollgate.

IV-3. Roman Aqueduct in France. Carpenter, Phys and others. 1961. Everyday Life in Ancient Times. Washington, D.C.: National Georgraphic Society. p. 272.

This slide shows an aqueduct built by the Romans (about 19 B.C.). It stands in southern France. The Romans knew how to make mortar but they did not have good quality cement. As a consequence, this entire bridge is put together with blocks of stone without the use of mortar. The upper portion of the aqueduct was used to carry water over great distances.

IV-4. Roman Medical Instruments. Nourse, Alan. 1964. The Body. New York: Time, Inc. p. 23.

The Romans established state supported hospitals, Roman medicare. This slide shows some of the surgical instruments used by Roman doctors. However, they were not concerned with the practice of medicine and employed Greek physicians. They had knowledge of Greek science but they chose not to extend this knowledge. Their emphasis was on applied science.

IV-5. The Paths of Alchemy (map). Choppin, R. and B. Jaffee. 1963. Chemistry: Science of Matter, Energy and Change. New York: Silver Burdett Company. p. 26.

The Greeks founded Alexandria, the Romans later conquered it, and in time Alexandrian science became more superstitious. One of the results of this superstition or religious flavor was alchemy. The alchemists took the theories of the Greeks and the craftmanship of the Egyptians and transformed it into what we call alchemy. The alchemist attempted to change various metals into gold but never succeeded. But they did more than just look for the philosopher's stone; they preserved the activity we call experimentation. Another contribution was the development of a process called distillation. Alchemy spread from Alexandria to the east to China and to the west to Spain and eventually Europe. In Europe amateur scientists picked up the practice of alchemy and eventually founded the science of medical chemistry.

IV-6. The Equipment of the Alchemist. Lapp, Ralph. 1965. Matter. New York: Time, Inc. p. 26.

This is some of the equipment used by alchemists to distill materials. Some of these pieces of equipment may be familiar to you if you have taken chemistry. The equipment is: Moors Head still; crucible; retort; clay vessel; mortar; and alembic. This equipment was used for grinding solids, performing reactions, filtering, and distillation.

IV-7. Arabian Alchemy. Lapp, Ralph. 1965. Matter. New York: Time, Inc. p. 26.

In later centuries, the Arabs absorbed alchemy into their practice of science. They helped to keep this activity alive for about 400 years and eventually passed on to the western world. The Arabs often used astrology as this picture indicates. The alchemist (really the war god Mars) is riding a bull (Taurus) and wields a scorpion (Scorpio). These were supposed to be good omens for the process listed above.

IV-8. Alchemy in the Middle Ages. Lapp, Ralph. 1965. Matter. New York: Time, Inc. p. 28.

Alchemy was practiced until about the 1800's at which time it was discredited. This slide depicts the discovery of the element phosphorus by Hennig Brand (a Homburg, Germany alchemist). Alchemists are credited with the discovery of bismuth, zinc, arsenic, and antimony.

IV-9. Map of the Moslem World. Neill, Thomas. 1968. Story of Mankind. New York: Holt, Rinehart and Winston. p. 250.

This map shows the world situation about A.D. 750. It shows how the Moslems controlled much of the land from India to the Pyrennes Mountains. It was through their work that science was preserved, especially Greek science. They collected any scientific knowledge that they could get and translated it into Arabic. As science became deemphasized in the east (in Damascus and Bagdad) Arab scientists moved westward and eventually settled in Spain. One of the key places was Cordoba. It was through the Arab scientist that western Europe became familiar with Greek science. The Arabs took the number system from India and eventually brought it to Spain where the Europeans adopted this system.

IV-10. Moslem Scientists. Benjamin, David. 1963. Mathematics. New York: Time, Inc. p. 71.

This slide shows the various activities performed by Moslem scientists. They were contributors to astronomy. In this painting they are seeking the course of stars using the Astrolabe, globe, and compasses. They used the most advanced mathematics of the day--al-gebra.

IV-11. Christian Scientist. Hay, Dennis. 1967. The Age of the Renaissance. New York: McGraw-Hill Book Co. p. 121.

This is a painting of St. Augustine who was considered by some to be an early Christian scientists. Notice that he has a globe (derived from Greek science). Behind him on the shelf is a book of Euclidian geometry. On the table is a bishop's miter.

IV-12. Early Christian Scientists - Monks. Benjamin, David. 1963. Mathematics. New York: Time, Inc. p. 72.

This slide shows three monks studying the stars. They are 13th Century stargazers. The individual in the center holds an astrolabe and a crude telescope. On the right an individual reads tables (written in Arabic) and on the left an individual records the observations.

IV-13. The Hill of Knowledge. Hay, Dennis. 1967. The Age of the Renaissance. New York: McGraw-Hill Book Co. p. 132.

This painting is entitled, "The Hill of Knowledge." It summarizes the attitude of man toward knowledge at the end of the Middle Ages. There are seven levels: the bottom level is grammar and the top level is theology. This indicates that religion or theology was considered to be a knowledge above that of science and all other disciplines at that time.

IV-14. Printing Press. Wilson, Mitchell. 1954. American Science and Invention. New York: Simon and Schuster. p. 36.

This is an 1813 edition of the priting press. It is more modern than the original Gutenberg press. The Gutenberg press used moveable type so that they could set up a page on a flat bed and then rearrange it for a new page. The old press used solid blocks of wood or stone on which the information would have been scratched or imprinted. The printing press using moveable type made it easier to put information on the printed page and revolutionized the spread of knowledge.

SLIDES - CHAPTER V

V-1. Trinity College, Cambridge. Hoyle, Fred. 1962. Astronomy. Garden City, New York: Doubleday and Co. p. 136.

The University and the scientific society were of value to science because they gave the scholar a place to spend time in study. This slide shows Trinity College, Cambridge. This is one of the first universities founded; it was the college attended by Isaac Newton in the 17th Century.

V-2. Journeys of Exploration and Commerce (Map). Neill, Thomas. 1968. Story of Mankind. New York: Holt, Rinehart, and Winston. p. 381.

This is a map of the world with the trade routes (about 1510). One of the motives for promoting science was to develop a way of determining longitude at sea. England, France, and in particular the Netherlands offered awards for anyone who could figure a way of determining longitude at sea. This encouraged scientists to study the problem, and gave much attention to the science of the Greeks, a science that was eventually challenged.

V-3. 16th Century Water Pump. Crombie, A. C. 1959. Medieval and Early Modern Science. Volume II. Garden City, New York: Doubleday and Company. p. 147.

Scientists were encouraged to find some means of draining mines. This diagram shows a pump powered by running water. Others were powered by horses or donkeys. It was this problem that led many scientists in search of a means of replacing the horse and water wheel.

V-4. Greenwich Observatory. Hoyle, Fred, 1962. Astronomy. Garden City, New York: Doubleday and Company. p. 147.

The search for a method of determining longitude at sea led to the establishment of astronomical observatories. The purpose of the observatories was to study the stars to get more accurate tables for navigators. This observatory in Greenwich, England sits on the imaginary line known as "meridian" (zero degrees longitude). Observe the equipment of the time: telescope; quadrant; and a pendulum clock.

V-5. Calendar Making. Goudsmit, S. A. and R. Claiborne. 1966. Time. New York: Time, Inc. p. 74.

This is an artist's conception of scientists employed by Pope Gregory to update the calendar. The calendar was off three days every 400 years. The Pope was looking for a more accurate calendar. By supporting this project the church helped promote the advancement of science.

V-6. Balistics Diagram. Bixby, William. 1964. The Universe of Galileo and Newton. New York: American Heritage Publishing Company. p. 127.

This diagram shows the path of a cannonball when fired by a cannon set at various elevations. This pioneer work was attributed to Galileo (the diagram was made by the artist Ufano in 1621). This problem, along with the previous problems, led scientists to review Greek science. They found that many Greek theories were not adequate and so they searched for new explanations.

V-7. Renaissance Scientists. Hay, Dennis. 1967. The Age of the Renaissance. New York: McGraw-Hill Book Company. p. 332.

This is Rembrandt's drawing of 16th and 17th Century scientists. On the table are various instruments used in astronomy, the dominant science at the time. Why was astronomy the dominant science?

V-8. Globe of the World in 1492. Hay, Dennis. 1967. The Age of the Renaissance. New York: McGraw-Hill Book Company. p. 207.

This is a globe of the world in 1492 and is similar to the one on the table in the previous slide. One thing is missing--the western hemisphere. The discovery and exploration of new lands motivated scientists to study navigation.

V-9. Sir Francis Bacon. Bixby, William. 1964. The Universe of Galileo and Newton. New York: American Heritage Publishing Company. p. 100.

This is what one advocate of science looked like in the early 1600's. This is Sir Francis Bacon, a lawyer and champion of the inductive method of studying science. He was not a scientist but a public servant who advocated the accumulation of facts in solving problems.

V-10. Galileo Galilei. Bixby, William. 1964. The Universe of Galileo and Newton. New York: American Heritage Publishing Company. p. 64.

Galileo was one of the pioneers in modern scientific methods. He believed in experimentation and observation as advocated by Francis Bacon and Rene' Descartes. One important thing to remember: Galileo started his experimentation before Bacon and Descartes wrote about their methods.

V-11. Chapel at Pisa. Bixby, William. 1964. The Universe of Galileo and Newton. New York: American Heritage Publishing Company. p. 10.

Galileo formulated the law of the pendulum. It has been said that he observed the swing of a chandelier on the ceiling of the Chapel at Pisa. This led to the development of the pendulum clock.

V-12. Pendulum Clock. Hoyle, Fred. 1962. Astronomy. Garden City, New York: Doubleday and Company. p. 121.

This is one of the first pendulum clocks ever made. As the pendulum swings it advances the gears.

V-13. Galileo's Telescope. Bixby, William. 1964. The Universe of Galileo and Newton. New York: American Heritage Publishing Company. p. 51.

These are telescopes developed by Galileo; they are on display in a Florence, Italy museum. These are the instruments Galileo used to study the moons of Saturn, the surface of the moon, and the planet Jupiter. It is with these instruments that he concluded that Aristotle's explanation of the universe was not adequate.

V-14. Ptolemy System. Bixby, William. 1964. The Universe of Galileo and Newton. New York: American Heritage Publishing Company. p. 14.

This and the following slide are artist's drawings from 1680 showing the universe according to Aristotle and Ptolemy and Galileo and Copernicus. The universe according to Ptolemy and Aristotle had the earth at the center with the other planets, the sun, moon, and stars revolving around it.

V-15. Copernican System. Bixby, William. 1964. The Universe of Galileo and Newton. New York: American Heritage Publishing Company. p. 15.

Copernicus, a Polish monk, believed that the sun was at the center of the universe and not the earth. He published his ideas but the publication was prefaced by a statement indicating that the idea was just a game. So no one paid any attention to him. Galileo showed that the evidence supported Copernicus; he was called before an Inquisition for supporting the Copernican system.

V-16. Monument to Galileo. Bixby, William. 1964. The Universe of Galileo and Newton. New York: American Heritage Publishing Company. p. 83.

Galileo was forced to recant his theories. The Inquisition placed him under house arrest where he remained until his death. Fifty years after his death, the city of Florence, Italy erected this monument to him.

V-17. Newton's Room. Bixby, William. 1964. The Universe of Galileo and Newton. New York: American Heritage Publishing Company. p. 87.

Another important amateur scientist of the 17th Century was Isaac Newton. He studied at Trinity College, Cambridge and later became professor of mathematics there. The room on the second floor is the room that Newton occupied as a student. It is unoccupied and preserved as a tribute to him.

V-18. Discovery of the Spectrum. Benjamin, David. 1963. Mathematics. New York: Time, Inc. p. 12.

Trinity College was closed for about two years (1665-1666) because of the black plague and Newton went to live with his mother on the farm. It was in a shed on this farm that he did experimentation which led to the discovery of the spectrum. At this time he also invented calculus, and did investigations that later led to the formulization of the laws of gravitation.

V-19. Newton's Telescope. Hoyle, Fred, 1962. Astronomy. Garden City, New York: Doubleday and Company. p. 56.

This is a telescope invented by Isaac Newton (1st Newton telescope - 1688). Instead of looking through the back of the telescope you look through an opening on the side. The light passes through the front to the back of the telescope and is reflected up to the observer. This is the type of telescope that is used in most observatories today.

V-20. Blake's View of Newton. Bixby, William. 1964. The Universe of Galileo and Newton. New York: American Heritage Publishing Company. p. 129.

This is a portrait of Newton drawn by artist and poet William Blake; he was not a follower of Newton. So he drew Newton as the devilish draftsman. To Blake, Newton's view of a mechanical universe was inhuman and repellent. So you see that great scientists such as Newton were not always popular in society.

V-21. Portrait of Newton. Bixby, William. 1964. The Universe of Galileo and Newton. New York: American Heritage Publishing Company. p. 7.

This is a painting of Newton. He is attired and seated to designate his position in the world. This is how this artist and many of his contemporaries viewed Newton.

V-22. Newton's Tomb. Ihde, Aaron. 1964. The Development of Modern Chemistry. New York: Harper and Row Company. Personal Photograph.

This slide shows Newton's tomb at Westminster Abbey. Although Blake and many others did not completely appreciate Newton's contributions the English Crown knighted him and after his death buried him in this tomb in Westminster Abbey.

SLIDES - CHAPTER VI

VI-1. Marine Chronometer. Hoyle, Fred. 1962. Astronomy. Garden City, New York: Doubleday and Company. p. 121.

This slide shows the solution to the problem of navigation. This is one of the first marine chronometers made. This instrument was not possible until the law of the pendulum was formulated. Although many scientists tried to perfect this instrument it was finally developed independently by an English clock maker and a French watch maker. A chronometer is nothing more than a clock which keeps very accurate time. But by having this instrument the sailors could figure out their longitude at sea.

VI-2. Newcomen Steam Engine. Wilson, Mitchell. 1954. American Science and Invention. New York: Simon and Schuster. p. 51.

This is the steam engine designed by Newcomen, an English blacksmith. James Watt improved on this instrument about 1760. This type of engine was the first piece of equipment that did not require horsepower, waterpower, or manpower. Steam from the boiler went into the cylinder and pushed the piston upward; the steam was condensed or released so that the piston would fall to the bottom of the cylinder. Teenage boys were hired to pour water on the cylinder or release the steam through a valve.

VI-3. English Industrial Town. Neill, Thomas. 1968. Story of Mankind. New York: Holt, Rinehart and Winston. p. 597.

VI-4. French Lecture Room. Wilson, Mitchell. 1954. American Science and Invention. New York: Simon and Schuster. p. 301.

The industrial revolution brought a change in scientific interest. Now electricity and chemistry rather than astronomy were emphasized. Scientific investigations went from amateurs to professionals. Science instruction went from apprenticeships to formal instruction. This is a physics lecture hall at Sorbonne University (19th Century); the equipment was used to demonstrate the phenomena known as "electricity."

The following set of slides are examples of accomplishments made by scientists and inventors during early United States history.

VI-5. Franklin Experiment. Wilson, Mitchell. 1954. American Science and Invention. New York: Simon and Schuster. p. 17.

Franklin was probably the first bonafide scientist in the U.S. He was curious about many aspects of nature. This slide shows Franklin and his son performing the famous kite experiment. It shows how facts can be confused and give the wrong impression. For example, his son was already an adult when the experiment was performed. Franklin never wore a fur hat until he was an old man. At the age of 46, when he performed this experiment, he was slim and athletic looking.

VI-6. Newburgh Fossil Excavation. Wilson, Mitchell. 1954. American Science and Invention. New York: Simon and Schuster. p. 41.

When Jefferson was President he offered Charles Peale equipment and assistance for the excavation of mammoth bones in Newburgh, New York (1801). This is probably the first time that the U.S. government offered assistance to a scientific enterprise. Two years later Jefferson directed Lewis and Clark to explore the newly purchased Northwest Territory for as Jefferson said, "similar specimens and unknown species."

The following sequence of slides shows you some of the inventions which were developed during the 1800's and early 1900's in the United States. Each of these inventions was developed to meet a particular need.

VI-7. Breechloading Gun. Wilson, Mitchell. 1954. American Science and Invention. New York: Simon and Schuster. p. 190.

This type of gun enabled men to defend fortresses without exposing themselves to enemy fire. They were used during the Civil War.

VI-8. Gatling Gun. Wilson, Mitchell. 1954. American Science and Invention. New York: Simon and Schuster. p. 194.

This is one of the first machine guns--called a Gatling Gun. It was invented by an M.D., Dr. Richard Gatling, during the Civil War. It enabled a small group of men to defend a site against a large enemy force. Gatling worked on the gun when he was not treating wounded soldiers; he finished it in 1862. The first gun fired 350 shots per minute.

VI-9. Self-Propelled Steam Tractor. Wilson, Mitchell. 1954. American Science and Invention. New York: Simon and Schuster. p. 238.

The invention of the steam engine enabled farmers and road builders to become less dependent upon horses. This type of steam engines were used to pull plows and road building equipment such as steam rollers. This 1886 development permitted mass production farming.

VI-10. Edison's Improved Phonograph. Wilson, Mitchell. 1954. American Science and Invention. New York: Simon and Schuster. p. 292.

This is one of the first phonographs developed by Edison (probably our most famous inventor-scientists). This is a forerunner of today's phonographs and dictation machines. Sound was inscribed in foil which was wrapped around a drum. Alexander Graham Bell used a roller made of shellac for recording.Victor Company (RCA) was started with Edison's patent.

VI-11. Kodak Camera #1. Wilson, Mitchell. 1954. American Science and Invention. New York: Simon and Schuster. p. 268.

Before the invention of this camera man had to record his observations by painting and sketching or by written description. Cameras such as these enabled man to make replicas of what he saw. This camera took 100 circular photos per roll of film; the camera cost $25 in 1880.

VI-12. Bell Telephone Experiment. Wilson, Mitchell. 1954. American Science and Invention. New York: Simon and Schuster. p. 282.

This slide shows Dr. Thomas B. Watson (March 15, 1877) awaiting the message from Alexander Graham Bell via the telephone. Since the U.S. was large and its population was fairly sparse there was a need for communication and transportation to connect distant communities. The telephone and telegraph helped to meet this need. Alexander Graham Bell not only invented the telephone but he also developed one of the first hearing aids; he did much work with people who had hearing problems. Alexander Graham Bell was one of the founders of the National Geographic Society which publishes National Geographic Magazine; it is still edited by his descendents.

VI-13. First Wright Airplane Engine. Wilson, Mitchell. 1954. American Science and Invention. New York: Simon and Schuster. p. 341.

Can anyone tell me what this is? What does it look like? It is the first airplane engine used by the Wright brothers; it was used in the Kitty Hawk (the first successful airplane). For centuries, man has attempted to fly but this was the first engine that enabled him to remain airborne for an extended period of time and land safely. The tin can at the top (an old tomato paste can) is the carburetor.

VI-14. Ford Assembly Line. Wilson, Mitchell. 1954. American Science and Invention. New York: Simon and Schuster. p. 326.

Can anyone tell me what this is? No, it is not a car wash. This is one of the early mass production assembly lines of the Ford Motor Company. Great distances between communities made an efficient form of travel necessary. Henry Ford was one of the pioneers in the development of the internal combustion engine. This picture was taken in 1912 at Highland Park.

VI-15. Josiah Willard Gibbs Plaque. Wilson, Mitchell.
1954. American Science and Invention. New York:
Simon and Schuster. p. 305.

Most people have never heard of this man but he is probably one of our first theoretical scientists. He did much theoretical work that was similar to the work of European scientists at that time. But since his work was not directly applicable to practical problems he was not nationally famous. However, in Europe he was well known and respected. Visiting European scientists would prefer to visit J. W. Gibbs than any other U. S. scientists. After his death Europeans came to the United States to honor him but most U.S. officials did not know who he was.

SLIDES - CHAPTER VII

VII- 1. *Wright Brothers' Glider*. Wilson, Mitchell. 1954. *American Science and Invention*. New York: Simon and Schuster. p. 340.

This is a glider made by the Wright brothers in the 1890's. I am showing you this slide to give you an example of the level of advancement of society at this time. This was the extent of aviation in the 1890's.

VII-2. *Dalton's Atoms*. Kogan, Philip. 1966. *The Cosmic Power*. Boston: Ginn and Company. p. 6

This slide shows the atom as proposed by Dalton. Atoms were considered to be solid spheres and were believed to be the "ultimate particle" of matter. These are symbols used by Dalton for various elements. In 1890, most scientists (except physicists) considered atoms to be the "ultimate particle."

VII-3. *Crooke's Tube*. Kogan, Philip. 1966. *The Cosmic Power*. Boston: Ginn and Company. p. 8.

This is a special type of cathode ray tube used for experimentation. High voltage is passed from the cathode (the round disk). The cathode rays (called electrons today) go from the cathode in this tube and strike the surface on the glass causing the glass to glow. The shadow on the glass is caused by the absorbtion of cathode rays by the metal cross. Thus, cathode rays could not pass through metal. While working with an apparatus of this type Roentgen discovered x-rays.

The following slides are examples of the uses of x-rays and the reaction of people to them.

VII-4. X-ray of Mrs. Roentgen's Hand. Hoyle, Fred. 1962. Astronomy. Garden City, New York: Doubleday and Company. p. 196

This is supposed to be the x-ray of the hand of Mrs. Roentgen. According to the story told, Roentgen was fascinated by these rays and asked his wife to put her hand on a photographic plate and took an x-ray of her hand. When she saw the x-ray photplate she was very upset. This was probably the second person ever x-rayed.

VII-5. Life Magazine Cartoon. Lapp, Ralph. 1965. Matter. New York: Time, Inc. p. 182.

This cartoon was a tongue in cheek view of x-rays. This was supposed to be a photo of the future. This cartoon appeared in Life magazine. It alludes to the ability to see the bones of your escort or date. This was considered to be too personal to be tolerated.

VII-6. Early Roentgen Apparatus. Ginger, Ray. 1959. Spectrum. New York: Holt and Company. p. 11.

Doctors recognized the value of Roentgen's discovery and immediately requested copies of Roentgen's machine. The viewer would look at a specially coated screen and the object to be x-rayed was placed between the screen and the cathode ray tube. This apparatus could probably x-ray a hand but not much more. Of course, it also needed a power supply.

VII-7. X-ray of a Hand. Lapp, Ralph. 1965. Matter. New York: Time, Inc. p. 181.

This is an x-ray taken in 1897 at Columbia University. It is an example of how quickly Roentgen's discovery was utilized. The spots on this x-ray are not defects in the film. They are buckshot. This man was injured in a hunting accident.

VII-8. X-raying Luggage. Lapp, Ralph. 1965. Matter. New York: Time, Inc. p. 183.

This sketch shows how x-rays were considered for use in the examination of luggage. At this time they did not know about the dangers of x-rays and so the cathode ray tube was set out on the table exposed and everyone there was exposed to damaging radiation. The man on the right is observing the contents of the luggage without opening it. The only thing he would be able to find is something that is opaque to x-rays such as metal objects, bones, etc.

VII-9. Becquerel's Discovery. Kogan, Philip. 1966. The Cosmic Power. Boston: Ginn and Company. p. 13.

In 1896 Becquerel investigated x-rays, but instead of answering questions he discovered a phenomena which asked more questions. This slide is an artist's conception of Becquerel observing the photographic plate that was exposed by uranium bearing salt. The salt crystals were exposed to sunlight and placed on photographic plates. The discovery of radioactivity resulted when a photographic plate was fogged by uranium bearing salt crystals that were not exposed to sunlight.

VII-10. The Curies. Grey, Vivian. 1966. Secret of the Mysterious Rays. New York: Basic Books, Inc. p. 33.

This slide is a photgraph of the Curies in their laboratory. It was an abandoned cadaver shed that was considered to be too old for the storage of cadavers. Pierre gave up his research work to help his wife in her search for polonium and radium. The laboratory was quite different from the well-equipped laboratories of today. It was in this laboratory that Marie Curie started her contributions to nuclear science.

VII-11. Uranium Ore. Ginger, Ray. 1959. Spectrum. New York: Holt and Company. p. 2.

This is a block of uranium from a mind in Colorado. The dark material is uranium oxide (UO_2). The element uranium was discovered in 1790, but no one had noticed the peculiar behavior of uranium ore until Becquerel discovered radioactivity. This block of ore weighs 100 pounds and contains about 80 pounds of uranium.

VII-12. *Polonium*. Lapp, Ralph. 1965. *Matter*. New York: Time, Inc. p. 141.

This disc, about the size of a quarter, contains a sample of polonium. The polonium is a fine film on the surface of the interior of the disc. If the whole disc were made of polonium and you owned it you would be a wealthy person, but you would have to protect yourself; polonium is extremely radioactive. Marie Cur discovered this element while studying the mystery of radioactivity.

VII-13. *Radium*. Lapp, Ralph. 1965. *Matter*. New York: Time, Inc. p. 130.

This vial contains a sample of radium. The photgraph was made from the light of glowing radium. This is the glow that Pierre and Marie Curie observed in the cadaver shed that momentous night.

VII-14. *Radioactive Water*. Lapp, Ralph. 1965. *Matter*. New York: Time, Inc. p. 188.

The people were not aware of the dangers of radium in the early years. This slide shows radioactive water that was sold for medicinal purposes. They used pure water but they added one of the most radioactive substances known to man. It was supposed to cure 160 ailments. One man drank several bottles a day for four years and died a horrible death. When this Pittsburgh businessman died in 1932 the producer of the water had to flee the country; if he would have stayed he would have been lynched.

VII-15. *Quackery*. Lapp, Ralph. 1965. *Matter*. New York: Time, Inc. p. 188.

This apparatus was supposed to have been used for the treatment of various respiratory diseases. It was heated with a burner and the individual would breathe the steam. Many contraptions such as this were used without caution. One doctor said that it filled a biblical prophecy; he called radium "the gentlest and most soothing healer the world has known."

VII-16. Rutherford Portrait. Blow, Michael. 1968. The History of the Atom Bomb. New York: American Heritage Publishing Company. p. 18.

This slide shows one of the best experimental scientists that has ever lived. His name is Ernest Rutherford. He and his assistants have contributed more to the basic research of radioactivity than any other group of scientists in the world. Rutherford was a keen experimentor because he was not willing to assume that small deviations in results were due to error. He always took special care in searching down the cause of the unusual results.

VII-17. Electric Properties of Radiation. Hoyle, Fred. Astronomy. Garden City, New York: Doubleday and Company. p. 27.

One of Rutherford's first contributions to the study of radioactivity was his analysis of radiation from radium. He used magnets to separate the radiation components. He called the radiations ray 1, ray 2, and ray 3 and named them after the first three letters of the Greek alphabet (alpha, beta, and gamma).

VII-18. Rutherford's Scattering Experiment. Choppin, R. and B. Jaffee. 1963. Chemistry: Science of Matter, Energy and Change. New York: Silver Burdett Co. p. 198.

Rutherford (with the assistance of Geiger and Mardens) used alpha particles to bombard gold foil. This slide shows a sketch of the experiment. The emitter (alpha) was in a lead box as shown. The alpha rays were directed toward a gold foil. Most rays passed through the gold foil but some were deflected through at small angles. Few were deflected through at greater angles or back toward the source. This led Rutherford to realize that the atom was not the solid sphere or like a plum pudding but mostly empty space.

VII-19. Rutherford-Bohr Atom. Grey, Vivian. 1966. Secret of the Mysterious Rays. New York: Basic Books Co. p. 79.

Since the atom could not be considered a solid sphere scientists were looking for a new model for the atom. Rutherford supplied them with a new model; he suggested that the atom was a miniature solar system as shown in this slide; the nucleus was the sun and the electrons were like miniature planets. The Rutherford model was later modified by Niels Bohr and others.

VII-20. Artificial Transmutation. Grey, Vivian. 1966.
Secret of the Mysterious Rays. New York: Basic
Books Company. p. 90.

This is a diagram of the apparatus used by Rutherford and Chadwick in their study of the nucleus. Alpha particles were emitted from a sample of radium. Ocassionally an alpha particle would enter the nucleus of a nitrogen atom and a proton was emitted. Rutherford could tell that this nuclear change took place because protons would strike the fluorescent screen. There was a thin sheet of metal between the source and the fluorescent screen. The particles striking the screen were not alpha particles. Later studies proved Rutherford's interpretation to be correct; he had succeeded in performing artificial transmutation.

VII-21. Transmutation Mechanism. Grey, Vivian. 1966.
Secret of the Mysterious Rays. New York: Basic
Books Company. p. 91.

This diagram shows what probably occurs in the reaction shown on the previous slide. An alpha particle with two protons and two neutrons penetrates a nitrogen nucleus that contains 7 protons and 7 neutrons. Now you have 9 protons and 9 neutrons. One of the protons is emitted from the nucleus. The nucleus now has 8 protons and 9 neutrons. Since an element's characteristics are determined by the number of protons in the nucleus, it no longer is a nitrogen atom but an atom with 8 protons in the nucleus which is oxygen. We now have the isotope oxygen 17.

VII-22. Nuclear Reactions. Kogan, Philip. 1966. The Cosmic
Power. Boston: Ginn and Company. p. 56.

The work of Chadwick and Rutherford led to further work in the transmutation of elements. These reactions indicate some possible nuclear reactions. The bombardment of nuclei eventually led to the discovery of neutrons, artificial radioactivity, and finally nuclear fission. This experimenttation showed that the nucleus consists primarily of protons and neutrons.

VII-23. Mass Spectrograph. United States Atomic Energy Commission. 1966. Nuclear Science. Oak Ridge, Tennessee. Division of Technical Information. p. 10.

This diagram shows the main part of an atom-weighing device known as the "mass spectrograph;" it is used to separate isotopes of an element. Before World War I, J. J. Thomson devised an apparatus for separating atoms of different weights. After the war, better equipment was developed and further experimentation showed that the elements had more than one kind of atom. The atoms differed in weight (or mass) but not in chemical properties. The heavier atoms contained more neutrons than the lighter atoms of the same element. This diagram shows neon 20 and neon 22. They are isotopes of neon. They both contain 10 protons but neon 20 has 10 neutrons and neon 22 has 12 neutrons. The difference in weight is due to the different number of neutrons. The discovery of the neutron helped to solve the mystery of isotopes.

SLIDES - CHAPTER VIII

VIII-1. *Albert Einstein*. Neill, Thomas. 1968. *Story of Mankind*. New York: Holt, Rinehart and Winston. p. 694.

This man is considered to be one of the greatest theoretical scientists that ever lived. Newton, Pythagoras, Democritus are put into the same category as Einstein who is shown in this slide. Einstein is known for his theory of relativity, but he is also known for another contribution. Although he was a pacifist he sent a letter to President Roosevelt that alerted the President to the possible dangers of atomic energy in the hands of the Nazi's.

The next two slides show the first and last of the ten dictators who came to power in Europe after World War I.

VIII-2. *Lenin*. Neill, Thomas. 1968. *Story of Mankind*. New York: Holt, Rinehart and Winston. p. 742.

Lenin was the first dictator to come to power in Europe after World War I. He set a trend followed by nine other ambitious individuals. The ambition of these men resulted in turmoil for the middle class and in particular the scholarly class. The insecurity felt by the scholars (or intellectuals) resulted in many of them migrating from country to country seeking a new homeland and better working conditions.

VIII-3. *Mussolini and Hitler*. Neill, Thomas. 1968. *Story of Mankind*. New York: Holt, Rinehart and Winston. p. 756.

These two men probably contributed more to the U.S. atom bomb project than any other individuals in the world at that time. Through their anti-Semitic and anti-intellectual policies they forced many well-qualified scientists to flee their countries. Most refugees of Hitler and Mussolini fled to the U.S. and England. They brought with them the knowledge of years of research pertaining to the atom and its nucleus.

VIII-4. Chicago Pile-1 Scientists. Groueff, Stephanie. 1964. The Manhattan Project. Boston: Little, Brown Company. photo section.

This slide shows the scientists who worked on the first atomic pile. They were led by Enrico Fermi in the first row and Leo Szilard who is in the second row. These two leading scientists were refugees of European dictatorships; Szilard was from Hungary and Fermi came from Italy. You will be shown a number of slides showing scientists who worked on the atom bomb. No composite photo is available so there will be a repetition of some individuals. This photo was taken December 2, 1946; the fourth anniversary of the first successful chain reaction.
Front row: Fermi, Zinn, Wattenberg, Anderson
2nd row: Agnew, Sturm, Lichtenberger, Leona Marshall, Szilard
3rd row: Hilberry, Allison, Brill, Nobles, Nyer, Wilkenburg

VIII-5. Hahn and Meitner. Blow Michael. 1968. The History of the Atom Bomb. New York: American Heritage Publishing Company. p. 25.

This picture shows Otto Hahn and Lise Meitner in their laboratory. This picture was taken before Lise went into exile. They raced the Joliot-Curies in the search for element 93 which Fermi thought that he had made. It was Hahn with the aid of Strassmann who did the chemistry that produced evidence that led to the discovery of nuclear fission. Lise Meitner and her nephew, Otto Frisch, were the first to recognize the significance of the experimental data.

VIII-6. Diagram of Half-Life. Kogan, Philip. 1966. The Cosmic Power. Boston: Ginn and Company. p. 36.

During our discussions we have talked about half-lives. This is a chart showing the activities of the isotope sodium 24. We will use this chart to discuss half-life. Let's assume we have a sample of sodium 24 and measure its activity. If we measure the activity again in 15 hours we find the activity is one-half of what it was in the beginning. If we wait another 15 hours and measure the activity it will be one-half of what it was 15 hours ago and one-fourth of what it was in the beginning. The activity decreases so that you have half as much as you did 15 hours ago. The isotope of sodium 24 has a half-life of 15 hours. If we started with one gram of sodium 24, after 15 hours (one half-life) there would be ½ gram of Na-24 left; after 39 hours (two half-lives) there would be ¼ gram; after another 15 hours (three half-lives)

VIII-6. Continued

there would be 1/8 gram left, then 1/16, 1/32, and so on. It is not known which atom is going to undergo decay but about half of the atoms of Na-24 should decay in 15 hours. Each element has its own half-life.

SLIDES - CHAPTER IX

IX-1. Map of the Trinity Site. Blow, Michael. 1968. The History of the Atom Bomb. New York: American Heritage Publishing Company. p. 73.

This section of the map is the shaded portion of New Mexico shown on this larger map. Alamogordo is in the southeast corner. The shot tower is known as Ground Zero where the first atom bomb was detonated. At distances of 10,000 yards, 10 miles, and 20 miles men observed the explosion. Compania Hill (the 11 o'clock position on the circle) is where reporter William E. Laurence observed the atom bomb tests.

IX-2. The Atom Bomb Test. United States Atomic Energy Commission. 1965. Plutonium. Oak Ridge, Tennessee. Division of Technical Information. p. 28.

and

IX-3. The Atom Bomb Test. Blow, Michael. 1968. The History of the Atom Bomb. New York: American Heritage Publishing Company. p. 84.

This and the next slide show what William Laurence and other observers saw at 0.05 second after the bomb was detonated. The scale on this first slide is 100 yards for the length shown. The dimension of this cloud is about five football fields across. The second slide shows the same explosion an instant later and reveals the characteristic muchroom cloud. These pictures were taken at Alamogordo on July 16, 1945.

IX-4. Ground Zero. Blow, Michael. 1968. The History of the Atom Bomb. New York: American Heritage Publishing Company. p. 87.

This is the site of the explosion. On this spot stood a steel tower from which the first bomb was suspended, a plutonium 239 device. After the explosion the tower completely disappeared and all that remained was the sand beneath the tower. The irregular-shaped objects are chunks of glass that formed when the heat of the explosion melted some of the sand.

IX-5. *The Manhattan District*. Groueff, Stephanie. 1964. *The Manhattan Project*. Boston: Little, Brown Company. Inside cover.

On December 6, 1941, the day before Pearl Harbor, the U.S. decided to embark upon the atom bomb project usually known as the "Manhattan Project." This diagram gives you an idea of the various facets of the "Manhattan Project" and some of the individuals involved in this work. The key places were Chicago; Hanford, Washington; Oak Ridge, Tennessee; and Los Alamos, New Mexico. The entire project was directed by General Leslie Groves; he was responsible to the Military Committee and Secretary Stimson. The project was so secret that most members of Congress did not know about its existence.

IX-6. *Administrators of the Manhattan Project*. Groueff, Stephanie. 1964. *The Manhattan Project*. Boston: Little, Brown Company. Photo section.

This picture shows the men who were primarily responsible for the administration of the Manhattan Project: Dr. Vannevar Bush, President of Carnegie Institute; Dr. James B. Conant, chemist and later President of Harvard University; General Leslie Groves, director of the Manhattan Project and U.S. Army Engineer; and Colonel Matthias, Groves' assistant.

IX-7. *Uranium Metal*. Lapp, Ralph. 1965. *Matter*. New York: Time, Inc. p. 148.

This is a bar of uranium metal which is the only naturally occuring source of fissionable material. A four-inch block of this material (about 35 pounds) will become a self-sustained chain reaction if penetrated by a stray neutron. If the 35 pounds is pushed together very rapidly, making a critical mass, an explosion will occur.

IX-8. *Isotopes of Uranium*. Grey, Vivian. 1966. *Secret of the Mysterious Rays*. New York: Basic Books Co. p. 97.

This diagram shows the two most abundant isotopes of uranium, uranium 235 and uranium 238. Note the difference between these two isotopes. They both contain 92 protons and 92 electrons. Uranium 235 has 143 neutrons and uranium 238 has 146 neutrons. Uranium 238 weighs 3 units more than U-235 due to the three extra neutrons. Uranium 235 was used in

IX-8. Continued

the atom bomb. Uranium 238 is converted by artificial transmutation into plutonium 239, also used in the atom bomb. The two isotopes were separated at facilities at Oak Ridge. U-238 was made into plutonium at Hanford, Washington (there were 9 nuclear reactors and facilities for separating plutonium from the other materials at this site). The uranium 235 and plutonium 239 were shipped to Los Alamos where they were fabricated into components of the atom bomb.

IX-9. *Pile Reactions*. United States Atomic Energy Commission. 1965. *Plutonium*. Oak Ridge, Tennessee. Division of Technical Information. p. 12.

These are the reactions that occur during the making of plutonium 239. Natural uranium is reacted by bombarding U-235 with slow neutrons. When U-235 undergoes fission neutrons are released that react with U-238 to produce U-239. The U-239 is converted to Pu-239 by the loss of two beta particles. Plutonium was spearated from other fission by-products and sent to Los Alamos (the bomb making center).

IX-10. *Plutonium Sample*. United States Atomic Energy Commission. 1965. *Plutonium*. Oak Ridge, Tennessee. Division of Technical Information. p. 1.

This is a picture of the first sample of plutonium magnified 20 times. This was the first weighable sample of Pu-239. The object in the upper part of the picture is the graphite portion of a pencil. This was all the plutonium we had in 1940, but by 1945, we had enough for two atom boms. One was tested at Alamogordo and the other was dropped on Nagasaki. Scientists used a sample this size to show that plutonium would undergo nuclear fission.

IX-11. *Plutonium Metal*. Lapp, Ralph. 1965. *Matter*. New York: Time, Inc. p. 148.

This is what plutonium metal looks like. If you had 16 pounds of this material in one chunk and it was penetrated by a neutron it would undergo fission. It is safe to store less than a critical mass of 16 pounds because it will not undergo a chain reaction.

IX-12. *Nuclear Fission Chain Reaction*. Grey, Vivian. 1966. *Secret of the Mysterious Rays*. New York: Basic Books Company. p. 115.

This diagram shows what occurs in a nuclear fission chain reaction. The key to the whole reaction is the release of neutrons. Assuming that you have one U-235 atom and it is bombarded by a neutron it splits and releases two or more neutrons which are free to bombard other uranium atoms. If one neutron is released for every neutron absorbed a chain reaction will result. This diagram shows an ideal situation in which one neutron and one U-235 atom start a reaction which eventually results in many U-235 atoms undergoing fission. The reaction is duplicated at a rate of 2, 4, 8, 16, 32, 64, and so on.

IX-13. *Moderated Chain Reaction*. Blow, Michael. 1968. *The History of the Atom Bomb*. New York: American Heritage Publishing Company. p. 38.

This diagram is similar to the previous one except a moderator has been placed in the reaction core to slow down the neutrons. The moderator can be heavy water or graphite. The Americans and the Germans knew about moderators because Fermi and his coworkers discovered the value of moderators in 1934. United States scientists found that graphite was a suitable moderator but the Germans thought otherwise. This was a fortunate mistake for us because the Germans had to rely on heavy water.

IX-14. *First Atomic Pile (CP-1)*. Blow, Michael. 1968. *The History of the Atom Bomb*. New York: American Heritage Publishing Company. p. 44.

This is an artist's conception of what the first nuclear reactor looked like. The pile gets its name from the fact that it is merely a pile of graphite blocks which is the moderator. Some graphite blocks had holes drilled in them and uranium and uranium oxide were placed in these holes. The man under the scaffold is removing the cadmium control rods. Cadmium, which is a good neutron absorber, is used to decrease the number of neutrons and therefore the rate of nuclear fission. The other man is observing the control panel. The pile was encased in a huge rubber balloon which was not needed. The men on the scaffold were known as the "suicide brigade;" they had bottles of cadmium salt solution which they were to dump on the reactor if it went out of control.

IX-15. Atomic Pile Photograph. United States Atomic Energy Commission. 1964. Nuclear Reactors. Oak Ridge, Tennessee. Division of Technical Information. p. 5.

This is an actual photograph of some layers of graphite in the first atomic pile. Note the layer of graphite blocks with holes drilled in them; the uranium and uranium oxide pellets were placed into the holes. The overlying layer consisted of solid blocks of graphite. As previously mentioned it was called an atomic pile because it was merely a pile of graphite bricks (the moderator) and uranium pellets (the fissionable materials).

IX-16. Wigner Chianti. United States Atomic Energy Commission. 1950. The First Reactor. Oak Ridge, Tennessee. Division of Technical Information. p. 24.

This is the bottle of Chianti that Eugene Wigner produced after the first successful chain reaction. It's difficult to make it out on the straw binding but the scientists present at the first reaction autographed this bottle.

IX-17. Mass Spectrograph. Kogan, Philip. 1966. The Cosmic Power. Boston: Ginn and Company. p. 45.

Earlier we discussed the principle of mass spectrography for separating isotopes. This is a more elaborate piece of apparatus. The heavier the isotope the further out it will swing before it is bent back to the photographic plate as shown. This is the principle used for separating isotopes in the mass spectrograph, the basic principle used in the electro-magnetic separation process used at Oak Ridge.

IX-18. Oak Ridge "Racetrack." Blow, Michael. 1968. The History of the Atom Bomb. New York: American Heritage Publishing Company. p. 64.

This apparatus, called the "Racetrack," was used to separate U-235 from U-238 by means of very strong magnets. The isotopes were whirled around the racetrack at very high speeds. The heavier isotopes moved to the outside of the loop and the lighter isotopes were directed toward the inside of the loop. Special separators were used to remove the U-235 from U-238. This apparatus required about a half billion dollars worth of silver wire. The entire racetrack is a series of magnets with a tube through which isotopes pass.

IX-19. "Racetrack" Control Room. Groueff, Stephanie. 1964. The Manhattan Project. Boston: Little, Brown Company. photo section.

This picture shows women who were used to control the racetrack separator. They were not trained engineers but ordinary housewives who worked during the war. They were taught how to operate certain controls and did not know what they were controlling. However, the women did as good a job as the men who designed the "racetrack."

IX-20. K-25 Gaseous Diffusion Plant. Groueff, Stephanie. 1964. The Manhattan Project. Boston: Little, Brown Company. photo section.

This series of buildings is known as the K-25 plant, another plant used to separate U-235 from U-238. In this case the uranium was made into a gaseous compound and passed through a series of filters until U-235 and U-238 were almost completely separated. The houses in the foreground are ordinary sized cottages. This plant was so large that workers had to use bicycles to get from one point to another. The plant required about 600 miles of pipe for the diffusion process.

IX-21. Gaseous Diffusion. United State Atomic Energy Commission. 1964. Atomic Fuels. Oak Ridge, Tennessee. Division of Technical Information. p. 12.

It has been known for many years that lighter gases move faster than heavier gases. The gaseous diffusion process is based on this principle. A gas is fed into these cylinders that have a barrier running through them. More of the lighter gas passes through the barrier than the heavier gas. If you continue cycling the gases through many barriers the lighter gas will be separated from the heavier gas. In this case the lighter gas contained U-235 and the heavier gas contained U-238. During World War II this was the main method for obtaining enriched U-235.

IX-22. The Gadget. Blow, Michael. 1968. The History of the Atom Bomb. New York: American Heritage Publishing Company. p. 60.

At Los Alamos, Oppenheimer was in charge of a team of scientists who were perfecting the atom bomb. One mechanism for the bomb was based on the rifle or gun principle. Two sub-critical pieces of U-235 are situated at the ends of the barrel; one piece is propelled into the other piece by TNT. When the two pieces come together a critical mass is assembled and a chain reaction occurs. The slide shows the other method used. A hollow plutonium sphere is surrounded by charges of explosives. The force of the detonated explosives forces the plutonium inward forming a critical mass. The gadget was made in such a way so that the force of the explosion would be inward; this is known as an implosion. The Pu-239 nuclear device utilized the implosion technique.

SLIDES - CHAPTER X

X-1. Toothpaste Ad. Irving, David. 1967. The German Atomic Bomb. New York: Simon and Schuster. photo section.

The Alsos Mission was responsible for investigating the German atom bomb project. They had to locate German nuclear scientists and their laboratories. They had one scare that turned out to be a bit humorous. A trainload of thorium ore disappeared and the Alsos investigators thought that the Germans had shipped it to Germany and that they were going to use it for atom bombs. But they found that one scientist, an executive with a toothpaste company, had shipped the thorium to the toothpaste company. He planned to use the thorium in toothpaste. This is a toothpaste ad for the company for which he worked before World War II. The top statement is as follows: I am the radioactive substance. My rays massage the gums. Good gums give good teeth. This was Doramad's answer to fluorides.

Following the bombing of Hiroshima German scientists claimed that they delayed the development of nuclear weapons for moral reasons; they said it was immoral to use nuclear weapons. However, the Alsos Mission and later investigations found that this was not true. The Germans were unsuccessful but not because of any moral issue. They lacked the drive and support of the Nazi leaders. In fact, the German nuclear scientists never progressed far enough in their research to be faced with a moral issue. The next few slides are evidence of the German attempt at developing a "uranium engine" (as they called it).

X-2. Leipzig Pile. Irving, David. 1967. The German Atomic Bomb. New York: Simon and Schuster. p. 119.

This was the first German atomic pile. They used heavy water for the moderator and uranium metal powder confined in aluminum containers. The Germans had proof before we did that a chain reaction was possible; they had this proof in May, 1942 while we obtained our first proof in December, 1942. But the Germans ran into political and scientific problems. The low supply of heavy water, the idea that graphite was

X-2. Continued.

unsuitable for a moderator, and several accidents delayed progress. The Germans ran into problems with this pile. Uranium powder burns when it comes in contact with air. When the Germans were refilling this pile the uranium powder burst into flames; the fire destroyed much of the pile shown. The German scientists held a meeting to organize their efforts under one controlling group, but leaders of the Nazi military did not attend the meeting. They were winning the war and did not see a need to attend the meeting.

X-3. Critical Pile at the Virus House, Berlin. Irving, David. 1967. The German Atomic Bomb. New York: Simon and Schuster. p. 148.

This pile was constructed in the Virus House at the Kaiser Wilhelm Institute for Medicine. Instead of using graphite or heavy water the German scientists used paraffin. They immersed the reactor in heavy water but it sprung a leak. The uranium reacted with the water and hydrogen was released. When the scientists removed the pile from the water it burst into flames and the hydrogen gas in the pile exploded and spread uranium powder in the laboratory. The entire Virus House burned down. Note that in all these atomic piles the Germans did not have control rods or any other means of control.

X-4. Haigerloch Uranium Pile. Irving, David. 1967. The German Atomic Bomb. New York: Simon and Schuster. p. 273.

This was the last German attempt to build a uranium pile. Suspended from the chain are uranium cubes (about 6 cm cubes) which were suspended in a vessel containing heavy water. They used ½ ton of uranium (78 chains, 664 cubes) and 1½ tons of heavy water. But no control rods. The graphite lid was set into place and a neutron source was inserted through a hole in the graphite lid. The German scientists were captured before they could complete their work.

X-5. Dismantling the Haigerloch Pile. Irving, David. 1967. The German Atomic Bomb. New York: Simon and Schuster.

This is an actual photo of allied soldiers dismantling this pile. This is proof that the German scientists were working on the "uranium problem."

X-6. Officials of the Manhattan Project. Groueff, Stephanie. 1964. The Manhattan Project. Boston: Little, Brown Company. Photo section.

This is a picture of some officials of the Manhattan Project. They were honoring Arthur Compton (center) for his contributions to nuclear science. They are General Groves, Bush, Fermi, Colonel Nichols, Pegram, Briggs, Thomas, Conant, Compton, Murphee, and Greenewalt.

X-7. Manhattan Project (S-1 Committee). Groueff, Stephanie. 1964. The Manhattan Project. Boston: Little, Brown Company. Photo section.

These are some of the leading U.S. scientists. The majority of responsibility was delegated to these men. The refugee scientists contributed much of the basic research and these men added their scientific and administrative talents. They are: Oppenheimer, Urey, Lawrence, Conant, Briggs, Murphee, Compton, Thornton, Colonel Nichols. Compton, Fermi, Oppenheimer, and Lawrence were advisers to the Interim Committee which recommended the use of the atom bomb against Japan.

X-8. "Little Boy." Blow, Michael. 1968. The History of the Atom Bomb. New York: American Heritage Publishing Company. p. 104.

This is a replica of the atom bomb dropped on Hiroshima. It weighed about 4,000 pounds and was about 10 feet long. Through the center of this bomb was a rifle barrel-like mechanism. One sub-critical portion was at one end of the bomb and the other sub-critical portion was at the other end. When the bomb dropped to an altitude of 1800 feet the radar mechamism set off a TNT charge which shot one piece of uranium 235 into the other and started the reaction.

X-9. "Fat Man." Blow, Michael. 1968. The History of the Atom Bomb. New York: A erican Heritage Publishing Company. p. 119.

The bomb shown here was called the "Fat Man." It was a plutonium 239 bomb; it weighed about 5000 pounds. It was about 10 feet long and contained the implosion type gadget. It was this type type of gadget that was tested at Alamogordo.

SLIDES - CHAPTER XI

XI-1. Japanese Surrender. Neill, Thomas. 1968. Story of Mankind. New York: Holt, Rinehart and Winston. p. 829.

This slide shows the signing of the Japanese surrender aboard the USS Missouri. It marked the end of World War II but the beginning of the cold war. Many claim that the dropping of the atom bomb contributed greatly to this situation. At the end of World War II scientists became nationally and internationally famous, in particular, those scientists associated with the development of the atom bomb.

XI-2. Steps in the Supply of Atomic Fuel. United States Atomic Energy Commission. 1964. Atomic Fuels. Oak Ridge, Tennessee. Division of Technical Information. p. 20.

This diagram shows the steps in the making of nuclear fuel. However, the steps for making nuclear explosives are essentially the same, which is why scientists insist on the international control of the production and utilization of radioactive materials.

XI-3. Plutonium Production Flow Diagram. United States Atomic Energy Commission. 1965. Plutonium. Oak Ridge, Tennessee. Division of Technical Information. p. 15.

This diagram is similar to the previous slide but shows the steps in the production of plutonium. Again, the end product can be used for fuel or nuclear weapons.

XI-4. Thermonuclear Triple-Threat. Lapp, Ralph. 1965. Matter. New York: Time, Inc. p. 174.

This slide shows the basic structure of a hydrogen bomb. This type of weapon along with missiles has made world destruction very possible. It is this threat which has prompted many scientists to seek international control of atomic energy. This weapon is known as a fission-fusion-fission device.

XI-5. Hydrogen Bomb Test in the Pacific. Blow, Michael. 1968. The History of the Atom Bomb. New York: American Heritage Publishing Company. p. 131.

This slide shows one of the first thermonuclear tests in the Pacific. It is hard to judge the size of the mushroom cloud. However, the dark spot in the water spout is the outline of a battleship that has been lifted out of the water.

The next three slides show some of the possibilities for peaceful uses of nuclear explosions. The big problem is control, or trust. The big question: Is the explosion being used for peaceful purposes or is it being used to perfect better weapons?

XI-6. Dam Building. United States Atomic Energy Commission. 1966. Plowshare. Oak Ridge, Tennessee. Division of Technical Information. p. 45.

This slide shows the possibilities for placing nuclear charges into the ground on the sides of the river and valley and detonating to form a natural dam across the river.

XI-7. A New Panama Canal. United States Atomic Energy Commission. 1966. Plowshare. Oak Ridge, Tennessee. Division of Technical Information. p. 39.

This is an artist's conception of building a new Panama Canal using nuclear explosives. If nuclear charges were placed at the point marked X and detonated the following channel would be formed. This would enable the building of a larger canal in much less time and for much less cost, but the same big question would arise.

XI-8. Sites for the New Panama Canal. United States Atomic Energy Commission. 1966. Plowshare. Oak Ridge, Tennessee. Division of Technical Information. p. 38.

These are possible sites for the new Panama Canal. The purpose of the Plowshare program is to find peaceful uses for nuclear explosives. The building of a canal may be one possible use for nuclear explosives. Can you think of others?

XI-9. Atomic Reactor Design. Kogan, Philip. 1966. The Cosmic Power. Boston: Ginn and Company. p. 87.

This is a simple diagram of an atomic reactor. There are basically three parts: 1) a moderator; 2) fissionable materials; and 3) control rods. The control rods are made of materials that are good neutron absorbers. When the control rods are inserted into the pile, neutrons are absorbed and the rate of fission decreases. The rate of nuclear fission will increase when the rods are withdrawn. As long as fissionable material is available the only control needed is a control of the number of free neutrons. One important thing about nuclear fission is that you do not need oxygen for the reaction.

XI-10. Cross Section of a Reactor. United States Atomic Energy Commission. 1964. Nuclear Reactors. Oak Ridge, Tennessee. Division of Technical Information. p. 3.

This is a type of reactor in which heavy water is used as a moderator.

XI-11. Energy Patterns Today. United States Atomic Energy Commission. 1964. Atomic Fuels. Oak Ridge, Tennessee. Division of Technical Information. p. 30.

This diagram shows our power sources today and how we use the power. Atomic energy has great potential for industrial applications. The problem at present is to develop the technology for the safe application of these resources. Radiation is the key problem in atomic energy. If we solve the problem of international control we still have to solve the problem of radiation.

XI-12. Breakdown of Costs. United States Atomic Energy Commission. 1964. Atomic Fuels. Oak Ridge, Tennessee. Division of Technical Information. p. 27.

This diagram compares the costs of a conventional plant and an atomic plant. Notice that the fixed charges are greater for an atomic plant; this is due to the fact that a large number of safety devices have to be included in the building of a nuclear plant. Operation and maintenance are greater because you must again consider the safety factors involved. The end products must be processed and great care must be taken in maintaining the facilities so radioactive materials do not escape. However, the cost is diminished greatly

XI-12. Continued

because the cost of fuel for an atomic power plant is much less. In the near future the cost of generating electricity by atomic energy may be less than that of fossil fuels.

XI-13. Basic Principles of Radioisotope Utilization. Illustrations of Radioisotopes. 1964. Oak Ridge, Tennessee. United States Atomic Energy Commission of Technical Information. p. 39.

This slide summarizes the technique used with radioistopes. The next series of slides will be examples of the types of techniques shown on this slide. The use of radioisotopes for heat and electrical sources is not shown.

XI-14. Food Irradiation Plant. United States Atomic Energy Commission. 1968. Food Preservation. Oak Ridge, Tennessee. Division of Technical Information. p. 25.

This is a diagram of a plant for sterilizing food. The materials are put into containers and sent into a special room where the food is irradiated by a radioactive source. When the food is removed from the treatment room it is germ-free and is not radioactive.

XI-15. Irradiation of Food. United States Atomic Energy Commission. 1968. Food Preservation. Oak Ridge, Tennessee. Division of Technical Information. p. 1.

This slide shows two potatoes that were picked at the same time and stored for 18 months. The one was irradiated and the other was not. This is an example of the potential of food irradiation.

XI-16. Radioisotopes for Gauging
and
XI-17. Radioisotopes for Gauging. Illustrations of Radio-Isotopes. 1964. Oak Ridge, Tennessee. United States Atomic Energy Commission of Technical Information. p. 127 and 45, respectively.

These two slides show the use of radioisotopes for controlling the thickness of sheet materials. The first slide shows the production of sandpaper in which the process is controlled by beta ray gauges. The second slide shows a backscattering technique of thickness control.

XI-18. Detecting Leaks.
and
XI-19. Leveling Gauge. Illustrations of Radioisotopes. 1964. Oak Ridge, Tennessee. United States Atomic Energy Commission of Technical Information. p. 134 and 128, respectively.

A radioactive source can be used for controlling the filling of containers to a predetermined level. When the liquid level reaches the radioactive source it absorbs the radiation and automatically turns off the supply of liquid.

XI-20. Radiography. Illustrations of Radioisotopes. 1964. Oak Ridge, Tennessee. United States Atomic Energy Commission of Technical Information. p. 140.

You probably have had x-rays of your teeth or bones. Radiography is a form of x-ray analysis that uses high energy x-rays. This method is used in industry to detect cracks, faults, and other defects.

XI-21. Test for Washing Efficiency. Illustrations of Radioisotopes. 1964. Oak Ridge, Tennessee. United States Atomic Energy Commission of Technical Information. p. 135.

Washing machine manufacturers utilize this technique to test the agitation action of washing machines. Radioactive dirt is applied to clothing to be washed. The amount of radioactive dirt removed indicates the agitation efficiency of the washing machine.

The following series of slides represents some of the uses of radioisotopes in medicine. The radioisotopes are chemically identical to other isotopes. When they enter the body, where they go depends upon their chemical properties only.

XI-22. Whole Body Scanning. Illustration of Radioisotopes. 1964. Oak Ridge, Tennessee. United States Atomic Energy Commission of Technical Information. p. 68.

This slide shows how an individual who has been given a radioactive cocktail is put on a special detecting device to determine sites of cancerous growths. The diagram on the right is what the operator of the scanning device sees.

XI-23. Iodine 131. Illustration of Radioisotopes. 1964. Oak Ridge, Tennessee. United States Atomic Energy Commission of Technical Information. p. 89.

This diagram shows how iodine 131 is used for diagnosing thyroid disorder or cancer. Patients drink an iodine 131 cocktail; the iodine goes to certain parts of the body and is then detected by special detectors.

XI-24. Sodium 24. Illustration of Radioisotopes. 1964. Oak Ridge, Tennessee. United States Atomic Energy Commission of Technical Information. p. 74.

This isotope is used for studying the circulation of blood in the body. The longer it takes for the sodium 24 to get to the extreme parts of the body the more restricted the flow of blood.

XI-25. Phosphorus 32. Illustration of Radioisotopes. 1964. Oak Ridge, Tennessee. United States Atomic Energy Commission of Technical Information. p. 76.

This slide shows two possible uses for phosphorus 32; both involve the principle of phosphorus 32 being absorbed by the bones. In one case the production of red cells is diminished; in the other case the production of white cells is reduced.

XI-26. Neutron Capture Therapy. United States Atomic Energy Commission. 1966. Radioisotopes in Medicine. Oak Ridge, Tennessee. Division of Technical Information. p. 34.

This is a method for the treatment of brain tumors. An individual is placed on a well-shielded table below which is a neutron source (Figure 1). A boron-bearing compound is injected into the individual (Figure 2). Because of chemical characteristics, the boron compound is absorbed by the brain tumor cells. After a period of time the tumor is subjected to neutron bombardment (Figure 3). The neutrons are captured by the boron and emit radiation. The alpha radiation is too weak to pass into the normal cells but it does attack and destroy the tumor cells. The neutron source is removed (Figure 4) and there is a good possibility that the tumor is destroyed. The key to success is early treatment. One problem exists: boron compounds are poisonous.

XI-27. *Cesium 137 Sample*. Ginger, Ray. 1959. *Spectrum*. New York: Holt and Company. p. 11.

This sample of cesium 137 is used in the radiation treatment of deep-seated cancers. This isotope as well as cobalt 60 is used in place of radium for a source of gamma rays. Note the size of this sample to the penny. The sample is worth about $20,000.

XI-28. *Rotational Teletherapy*. *Illustrations of Radioisotopes*. 1964. Oak Ridge, Tennessee. United States Atomic Energy Commission of Technical Information. p. 85.

This diagram shows how deep-seated cancers are treated. The radiation source could be radium, cobalt 60, or cesium 137. This apparatus can be used to treat small affected areas of the body without causing harm to other parts of the body.

SLIDES - CHAPTER XII

XII-1. Nuclear Treaty of 1963. Benjamin, David. 1963. Mathematics. New York: Time, Inc. p. 145.

This photo shows the signing of the 1963 nuclear treaty in which many nations agreed not to test nuclear weapons in the atmosphere. All nations, except France and China, have signed this document. This treaty and the nonproliferation treaty (1968) are steps in the right direction but we have a long way to go.

XII-2. Risks of Nuclear Energy. United States Atomic Energy Commission. 1969. Nuclear Power and the Environment. Oak Ridge, Tennessee. Division of Technical Information. p. 12.

The purpose of this slide is to show that it is possible for radiation to go from a nuclear reactor into the environment. When we have international control of atomic energy we still have to be concerned about the addition of radiation to the environment. Extremely careful treatment prevents most radiation from escaping into the environment but some does escape.

XII-3. Table of Radiation Dosage. Illustration of Radioisotopes. 1964. Oak Ridge, Tennessee. United States Atomic Energy Commission of Technical Information. p. 23.

This table shows the various types of radiation and its effect on the body. It is not important to know the values of the radiation but you should know that alpha particles are the most effective particles of radiation. Although alpha particles are not dangerous externally they can cause great internal damage.

The next three slides show ways in which radioactive materials are disposed.

XII-4. High Intensity Radioactivity Storage. United States Atomic Energy Commission. 1966. Radiation Wastes. Oak Ridge, Tennessee. Division of Technical Information. p. 23.

This slide shows one way of disposing of intensely radioactive waste materials from a nuclear reactor. These watertight cantainers are buried in the ground and covered with three feet of soil.

XII-5. Underground Mine Storage. United States Atomic Energy Commission. 1966. Radiation Wastes. Oak Ridge, Tennessee. Division of Technical Information. p. 35.

This is another possible method for storing intensely radioactive materials. Scientists hope to eventually use these waste materials for sources of industrial heat. At present no workable technique has been developed. This is a salt mine (Casey Salt Mine) in Lyons, Kansas.

XII-6. Low Intensity Radioactivity Treatment. United States Atomic Energy Commission. 1966. Radiation Wastes. Oak Ridge, Tennessee. Division of Technical Information. p. 15.

This slides shows a tank in which the low intensity radioactive materials are permitted to stand, eventually diluted with water, and returned to neighboring bodies of water. The question of importance is: Will we eventually contaminate our food supplies using this method? At the moment, no one knows the answer.

XII-7. Radiation Absorption. Illustrations of Radioisotopes. 1964. Oak Ridge, Tennessee. United States Atomic Energy Commission of Technical Information. p. 34.

This slide shows the various absorptive qualities of materials. The thing I would like to call to your attention is the tissue in the lower right hand corner. All the beta rays and alpha particles and about 60 percent of the gamma rays are absorbed by the body tissue. The absorption of these rays can result in the destruction of molecules in the body.

XII-8. Chromosome Damage. United States Atomic Energy Commission. 1966. Genetic Effects of Radiation. Oak Ridge, Tennessee. Division of Technical Information. p. 26.

This slide shows the chromosomes of cells which are undergoing cell division. The one cell is normal and the other cell is abnormal due to irradiation. Note the incomplete fission of the chromosomes in the abnormal cell. This is one of the main concerns of scientists in radiation biology.

XII-9. Effects of Radiation. Alexander, Peter. 1957. Atomic Radiation and Life. Baltimore: Penguin Books. photo section.

Radiation cannot be detected by any of the senses. This is the right hand of a pioneer radiologist (identity unknown) who worked with radioactive atoms without knowing the harmful effect of radiation. He worked with radioactive materials from 1896 to 1899 before the effects became noticeable. This is how his hand looked in 1932 when it had to be amputated; he died in 1933 of radiation sickness.

XII-10. Innocence. Lapp, Ralph. 1965. Matter. New York: Time, Inc. p. 188.

This is how scientists worked with radium in the early years before they knew the ill effects of radiation. This man is drawing a radioactive solution into a pipette and leaning over an evaporating dish containing a radioactive solution. This type of practice is not permissible today; national and international safety regulations would not permit it.

XII-11. Bone Cross-Section. United States Atomic Energy Commission. 1966. Radiation Wastes. Oak Ridge, Tennessee. Division of Technical Information. p. 26.

This is a cross-section of bone of a person who worked in a watch factory and died of radium poisoning. Painters of watch dials used to wet their paint brushes with the tip of their tongues. In doing so they introduced radium into their bodies; the radium settled in the bones and later caused great radiation damage. Many of these workers died from radiation sickness.

XII-12. Bone Cross-Section (Self-Portrait). United States Atomic Energy Commission. 1966. Radiation Wastes. Oak Ridge, Tennessee. Division of Technical Information. p. 27.

This slide shows the same piece of bone as the last slide but it is a self-portrait made by the bone. Radiation is responsible for the darkened areas on the photographic plate. The radiation from the bone was used to make this photograph.

XII-13. Radiation Detection Machine. Kogan, Philip. 1966. The Cosmic Power. Boston: Ginn and Company. p. 17.

Modern safety standards are very strict and strongly enforced. This slide shows a radiation detection machine which is situated at the exits of laboratories using radioactive materials. Workers must submit themselves to this inspection each time they leave the laboratory building. This is one safeguard established by the Atomic Energy Commission and international radiological agencies.

XII-14. Hot Laboratory Experimentation. Benjamin, David. 1963. Mathematics. New York: Time, Inc. p. 146.

Another safeguard against radiation is the use of mechanical manipulators to perform experiments. The purpose of this thick glass and walls is to protect the worker from lethal radiation.

XII-15. Models of Matter. Gallant, Roy A. and Lee J. Ames. 1958. Exploring Chemistry. Garden City, New York: Doubleday Company. p. 84.

Now that we have completed this unit, let's review man's view of matter. These are the ways that matter has been viewed by man throughout history: 1)Thales' concept that water was the primary substance; 2) a number of scientists, especially the Greeks, believed that fire may be one of the elements; 3) the ideas of Empedocles and Aristotle combined; 4) the atom as viewed by Leucippus and Democritus; 5) the atoms in a solid as viewed by Gassendi; 6) Dalton's atoms; 7) atoms as viewed by Michael Faraday (smoke rings); 8) the Thomson plum-pudding atom; 9) the pairing of positive and negative charges as viewed by Lennart; 10) the solar system atom as proposed by Rutherford; 11) the Bohr atom; and 12) the atom as viewed by scientists today, where we know

XII-15. Continued

that the atom has a nucleus but we do not know the position of the electrons that surround the nucleus. As you can see atoms have been viewed differently by different societies.

XII-16. Span of Time. Barnet, Lincoln. 1962. The Epic of Man. New York: Golden Press. p. 168.

This is the last slide. It shows how far society in some parts of the world has come and how far society in other parts of the world has to go. This is an Indian Airbase with modern jet planes. In the background is a modern plant that produces jets, buses, and automobiles. Passing alongside the airplanes are ox carts that have been used in this part of the country for the last 5,000 years. As you can see, science has benefited some nations tremendously but it has not been utilized in other countries. Developing nations such as Libya, India, Brazil, etc. could benefit from a well-established scientific community. How will science help these countries? Only future generations will know.

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